THE UNIVERSITY OF ALBERTA

GEOLOGY OF THE BELLSHILL LAKE OIL FIELD, EASTERN ALBERTA

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled GEOLOGY OF THE BELLSHILL LAKE OIL FIELD, EASTERN ALBERTA submitted by Gerard L. M. Cartier in partial fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

In the Bellshill Lake area, Mannville Group sediments directly overlie Paleozoic rocks. The topography of the pre-Mannville surface as outlined by an isopach map of the Lower Cretaceous beds is characterized by the presence of the valley of an Early Cretaceous river, which drained the region east and southeast of the Bellshill Lake area and flowed northward into an arctic sea. The valley crosses the Bellshill Lake area from east to west and seems to constitute one of the upper arms of the Edmonton Channel.

Starting in late Barremian, the first sediments which were deposited on the eroded Paleozoic surface were continental in origin (McMurray Formation). Continental conditions prevailed until the arrival of the Clearwater sea in Middle Albian time, then the sea withdrew toward the north (Fort Augustus Formation).

An outstanding feature of the local stratigraphy is the existence of a channel-fill sandstone at the base of the Fort Augustus Formation. This channel whose pattern was found to be markedly meandering, has been mapped in the Bellshill Lake area.

Sandstones of the Ellerslie Member are quartz sandstones, those of the "Calcareous" member and channel are transitional between quartz and lithic sandstones, while those of the Fort Augustus Formation are lithic sandstones (Travis, 1955). Most of the Mannville Group sandstones are cemented, essentially by calcite, the main source of carbonate coming from the erosion of Paleozoic limestone beds.

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CHAPTER 1

INTRODUCTION

General Statement

Starting with Badgley (1952), a number of authors, among them Glaister (1959), Williams (1960), and Mellon (1967) have studied the Mannville Group in the subsurface of central Alberta. Although the terminology used was modified slightly in the last of these studies, the stratigraphy of the group seems to be fairly well established now and reasonably accurate correlations may be made with adjacent areas such as the McMurray and Peace River areas, and the Alberta Foothills.

Therefore it seems that emphasis might now be given to more localized areas of central Alberta where particular problems, either stratigraphic or petrologic, occur. It is evidently out of the question to suppose that these studies of local interest may permit stratigraphic conclusions to be drawn on the regional scale (central Alberta) as only the local stratigraphy may be studied and the terminology to be used must generally be borrowed from a wider ranging study. On the other hand emphasis may be given to the geometry and petrology of units, which is sometimes decisive and sufficient for interpretation of particular local problems in this type of sediment where fossils are often absent or non-diagnostic. The present study of the Mannville Group in the Bellshill Lake area is to be classed among these types of studies.

Scope of the Project

The Bellshill Lake area is located in Alberta, about 100 miles

southeast of Edmonton and about 60 miles west of the Saskatchewan border (see map Fig. 1). The studied area, square-shaped, covers 9 townships, centered on Township 41, Range 12 west of the Fourth Meridian.

The study of the Mannville Group in the Bellshill Lake area was undertaken for several reasons. The main one was the presence in the area of an important, though localized, thickening of the McMurray Formation sandstones of the Lower Mannville Group. This feature is of considerable interest as it is directly responsible for the existence of the oil and gas accumulation in the Bellshill Lake and Thompson Lake fields. Only a few authors (Rudolph, 1959; Conybeare, 1964, 1967; and Martin, 1969) have discussed these hydrocarbon accumulations. To the writer's knowledge no comprehensive study of the area has been published.

Another reason, though related to the fact above, was that the maximum extent of the Clearwater transgression toward the south, as outlined by Williams (1960) seemed to correspond to the Bellshill Lake area. Under these conditions, one could wonder if the thickening of the McMurray sandstones could actually represent a near-shore type marine deposit linked to the Clearwater transgression (beach deposit, barrier-island ...).

A third reason centered on studying the pre-Mannville paleotopography, the geometry and stratigraphy of the different units and the petrology of the sandstones which represent a good deal of the deposits encountered, in order to set the studied area within the pattern proposed for the whole of Central Alberta by the different authors.

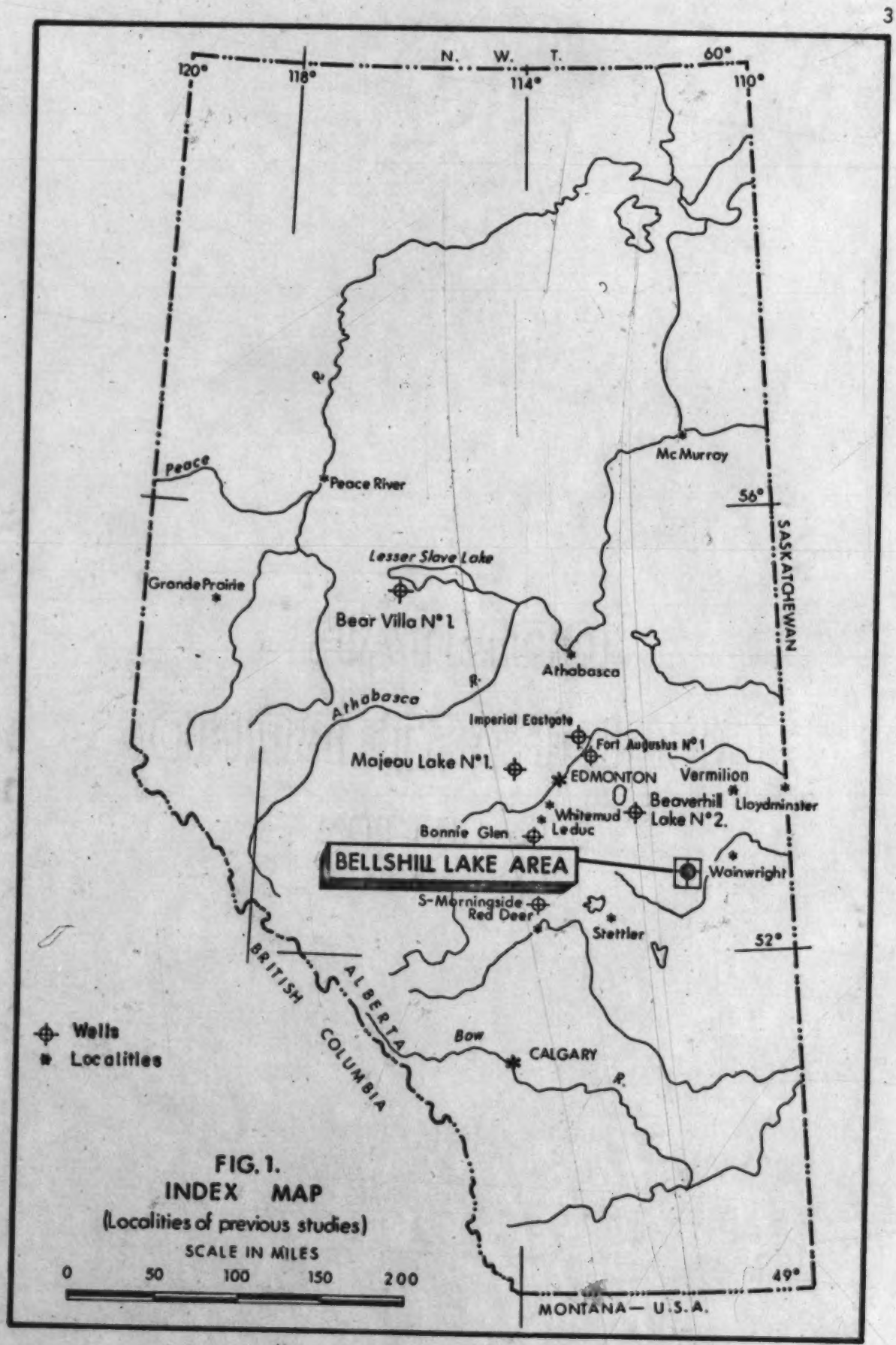


FIG. 1.
INDEX MAP
(Localities of previous studies)

The objectives ascribed to the present study may be summarized as follows:

1) To outline in detail the paleotopography on which the lowermost sediments of the Mannville Group were laid down in an area surrounding the Bellshill Lake oil field.

2) To study the geometry and local stratigraphy of the different units of the Mannville Group.

3) To study the detailed petrology of the sandstones of the Mannville Group.

4) To propose an explanation for the local thickening of the sandstones of the McMurray Formation in the Bellshill Lake area.

5) To outline the regional paleogeography and evaluate the depositional environment of the Mannville Group in the area of study.

Material Used - Methods of Investigation

All the electric logs of the wells drilled prior to 1970 (about 265 wells) were used in constructing stratigraphic cross-sections and the subsurface maps of the area. Sixteen wells (see Appendix A for locations) were chosen for a detailed study of cores, on the basis of their location with regard to the main features of the area and the availability of cores. Distribution of cores did not make the study easier, as in Township 41, Range 12 west of the Fourth Meridian, where almost all the wells studied in detail are located, most of the cores come from the reservoir unit of the Bellshill Lake field and therefore correspond almost always to the same stratigraphic level. About 1000 feet of cores from the seventeen wells were described in detail with the aid of the binocular microscope

(core descriptions - Appendix C).

Size analysis was done by sieving on nineteen sandstone samples from the McMurray Formation (for location of samples, see Appendix B). Sieving data were processed on the IBM 360/67 computer of the University of Alberta, Computing Center, using a program written for the Department of Geology, to determine the usual statistical parameters and plot the main size distribution curves of the sediments.

Fifty thin sections of the McMurray and Fort Augustus Formations were prepared (for location of samples, see Appendix B). Due to the high degree of friability of most of the sandstones studied, about half of the samples had to be treated by injection of resin before the thin sections could be prepared. The point count method was used to analyse twenty thin sections, in order to obtain the precise composition necessary for the classification of sandstones.

These different methods of investigation when taken together in the context of the pattern currently developed for the whole of Alberta, permitted an interpretation to be made of the paleogeography and depositional environment existing in the Bellshill Lake area early in Cretaceous time.

CHAPTER 2

THE MANNVILLE GROUP IN CENTRAL ALBERTA

Review of Previous Work

Lower Cretaceous rocks do not crop out in central Alberta, thus it is in areas situated farther north along the Athabaska and Peace Rivers that they were first described and studied in the latter part of the nineteenth century. Consequently many of the names applied in central Alberta originated elsewhere (Grand Rapids, Clearwater, McMurray, etc.).

The first studies on the Lower Cretaceous sediments in central Alberta were carried out in the eastern plains (Wainwright-Lloydminster-Vermilion area - see map Fig. 1) by Hume and Hage (1940, 1941), Nauss (1945, 1947), who introduced the name Mannville Formation and attempted the first stratigraphic divisions, and by Wickenden (1948).

Little was known however of Lower Cretaceous strata in the central plains until the discovery of the Leduc oil field in 1947. Extensive drilling which resulted from this discovery added immensely to the knowledge of regional stratigraphy.

The first publications which followed, dealing with the Lower Cretaceous in central Alberta, were descriptions of sections encountered in wells, mostly in the Edmonton area. Thus Kidd (1948), Andrichuk (1949), Layer (1949), Hunt (1950), and Lockwood and Erdman (1951) reported on sections found at the Anglo-Canadian Oil Company et al Beaverhill Lake No. 2 well (11-11-50-17W4), the Texaco-McColl Majeau Lake No.1 well (12-1-57-3W5) and Leduc, Whitemud and Stettler oil fields respectively (see map Fig. 1).

More specifically, paleontology-oriented work done by Nauss (Vermilion area, 1947), Loranger (Edmonton area, 1951) and Nikiforuk (Bear Oil Company Villa No. 1 well, 7-8-74-14W5, 1956) must also be mentioned.

The first comprehensive study of Lower Cretaceous sediments in subsurface central Alberta was by Badgley (1952). Subsequent reports were respectively by Workman (1958, 1959), Glaister (1959) and Williams (1960, 1963). More recently, Williams et al. (1962) dated detrital feldspars and authigenic glauconite from the Mannville Group of central Alberta, Singh (1964) studied the microflora of the Mannville Group in east-central Alberta, and Campbell and Williams (1965) dealt with the chemical composition and depositional environment of Mannville Group shales of central Alberta using the X-ray fluorescence method.

Mellon (1967) in dealing with the stratigraphy and petrology of the Blairmore and Mannville Groups, modified the earlier terminology by introducing the term Fort Augustus Formation.

Previous Work in the Studied Area

Besides the above work, the scope of which generally comprises the Bellshill Lake area, only a few authors have dealt with the Mannville Group within the studied area.

Rudolph (1959) reported on the Bellshill Lake field discovery in 1955, referring to the regional geology and Lower Mannville stratigraphy. Dealing with the major erosional low that occurs in the central part of the area under consideration, he mentioned in particular that " . . . the bordering highlands were undoubtedly the source of part of the lower Blairmore sediments laid down in this trough, and their

configuration probably affected the currents which caused the development of the sand bars within the Basal Quartz section of the Lower Cretaceous, such as at Bellshill Lake".

Conybeare (1964, 1967) and Martin (1966) referred to the Bellshill Lake field in their study of oil accumulation in stratigraphic traps. They both attributed an eroded fluvial terrace origin to the massive sandstone section of the Bellshill Lake and Thompson Lake fields.

Since then, numerous wells have been drilled in the area especially in a northwestern extension of the Bellshill Lake field in Sections 31 (Township 41, Range 12 W4) and 36 (Township 41, Range 13 W4), adding to our knowledge of local stratigraphy as well as particular geometry of the sandstone succession at the base of the Mannville Group.

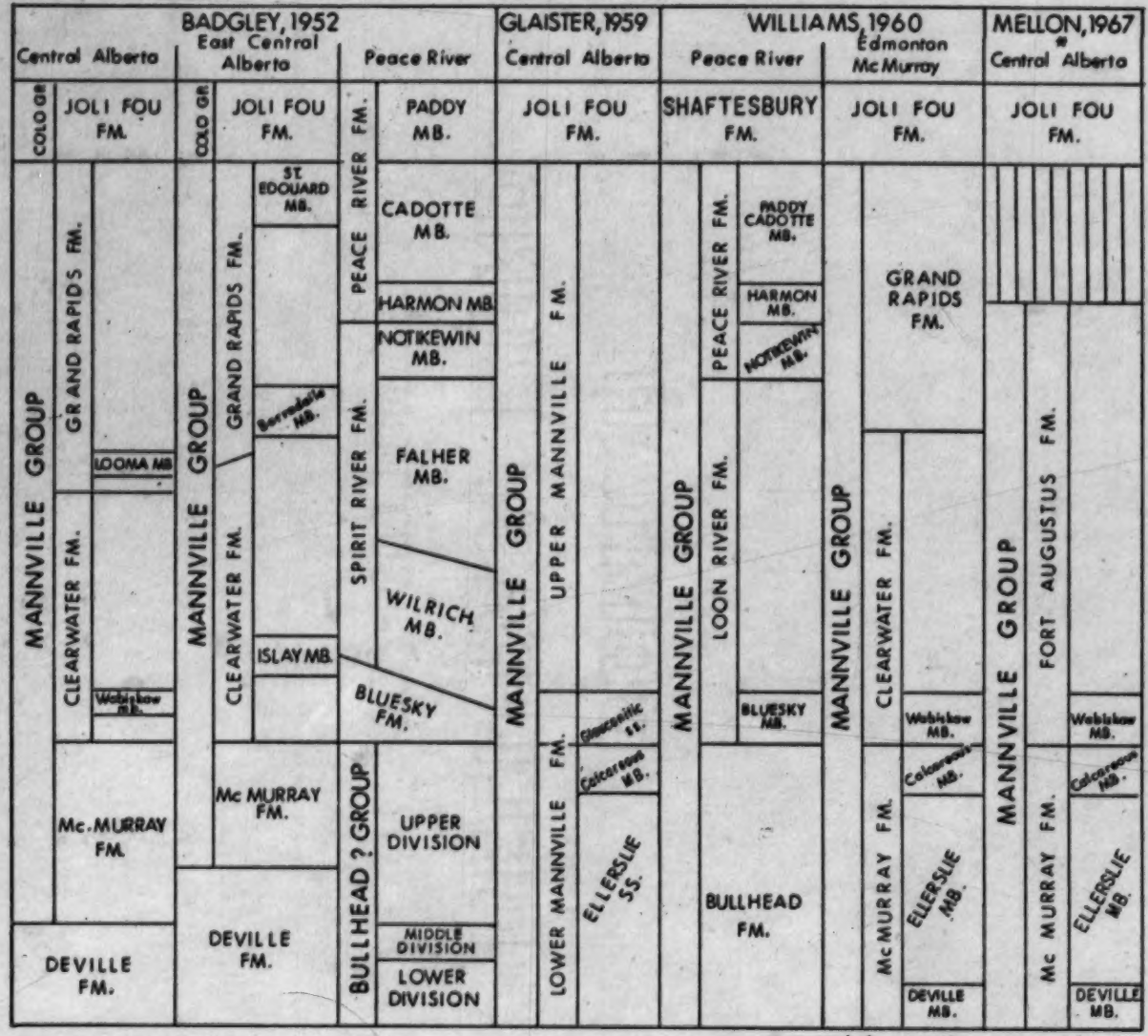
Stratigraphy of the Mannville Group in Central Alberta

Two transgresssions occurred in western Canada during Albian time. The first one, associated with the Mannville deposits, thus the only one that one is concerned with in this study, began in late Lower or early Middle Albian time.. It was an invasion by a boreal sea which reached its maximum southward extent in Middle Albian time and then retreated northward.

As Williams (1960, p. 20) pointed out, ". . . the fundamental simplicity of the stratigraphic pattern developed by this transgression-regression cycle has been largely obscured by proliferation of local names and lack of regional correlations".

The terminology used successively by the different authors to whom reference is made above has been summarized in Table I.

Williams' (1960, 1963) terminology for the Mannville Group in



* Used in this work

(after Williams, modified) 1960

TABLE I.

Terminology of the Mannville Group

the Edmonton area includes the McMurray, Clearwater, and Grand Rapids Formations, in ascending order. The McMurray Formation is in turn divided into Deville, Ellerslie and "Calcareous" Members, whereas the lower part of the Clearwater Formation is termed the Wabiskaw Member.

The name Fort Augustus Formation was proposed by Mellon in 1967 for the upper part of the Mannville Group in the central Alberta plains, above the "Calcareous" member of the McMurray Formation and below the marine Joli Fou shale. The Fort Augustus Formation, by this definition, is strictly the equivalent of Williams' Clearwater and Grand Rapids Formations.

Mellon's terminology, the twofold subdivision of which best fits the Mannville sequence encountered at Bellshill Lake, was used in this work.

CHAPTER 3

PALEOTOPOGRAPHY

Sub-Mannville Surface Structure Contour Map

In the Bellshill Lake area Lower Cretaceous strata directly overlie Paleozoic rocks. The pattern indicated by the Paleozoic surface structure contour map (Fig. 2) is the outcome of both the configuration of the Paleozoic substratum prior to deposition of the Mannville Group, and the present regional dip toward the centre of the Alberta syncline (NNW-SSE trend of contours).

Though somewhat overshadowed by the general southwesterly regional dip, a certain number of anomalies of N-S or NNE-SSW trend appear, the aspect of which suggests the presence of valleys sculptured on the Paleozoic surface, for example, in Township 41, Range 13 W4M, Township 42, Range 13 W4M, and Township 40, Range 11 W4M.

As the regional dip is relatively constant over the entire area, it may also be suggested that every variation in the density of contour lines is related to "breaks" in the Paleozoic surface paleotopography. If this may be assumed, it would then seem that a major low would exist in the central part of the mapped area, stretching from NW to SE from Township 41, Range 13, W4M to Township 40, Range 11, W4M.

As Rudolph (1959) pointed out, the topographically high feature trending southeast beneath the Bellshill Lake field ". . . looks much more spectacular than it really is, there being only about 10 to 20 ft. of relief on the Paleozoic . . ." (p. 889).

These different observations will generally be confirmed by the isopach map pattern.

Lower Cretaceous Isopach Map

The Base of the Fish Scales marker, the widespread extent of which is well known in Western Canada, has been used to construct an isopach map of the Lower Cretaceous deposits (Fig. 3). Provided no tectonic phenomena took place during the time in which the strata were deposited, which is generally thought to be the case in the area under consideration, this map represents the best tool to use to reconstruct the paleotopography prior to deposition of the Mannville, as it allows the removal of the regional dip. The Base of the Fish Scales marker was also used as datum for the construction of stratigraphic cross-sections.

Due to differential compaction phenomena which take place between sections where thick sand bodies occur and sections where shales are prominent, it must always be kept in mind that the above isopach map does not perfectly reflect the paleotopography of the Paleozoic surface. Sections where thick sand bodies are present would tend for this reason to appear as "lows" compared to adjacent sectors where shales predominate. In order to eliminate these phenomena as much as possible, the Base of Fish Scales structure contour map has always been consulted in the interpretation of the isopach map.

Paleotopography

The topography of the Paleozoic surface prior to deposition of the Mannville Group was characterized in the studied area by an elongated "low" stretching SE-NW from Township 40, Range 11, W4M to Township 41, Range 13, W4M; then bifurcating toward the southwestern corner of Township 41, Range 13, W4M.

In detail, the flanks of this feature are very irregular in

shape (the apparent regularity of the southwestern slope seems to be only due to the lack of well control in this sector), showing a series of secondary tributary "lows" connecting almost perpendicularly to the central valley feature. Maximum topographic relief within the studied area is close to 200 ft.

The pattern indicated by the map has been interpreted as an ancient valley and its tributaries. Due to the lack of well control in the area where the river bottom seems to be situated, it is difficult to determine accurately the width of the valley bottom; however it may have been as much as 3 miles wide.

Most of the studied area is occupied by the bed and the gentle flanking slopes of this valley. Only the northern part of Township 42, Range 11, W4M might constitute a sort of flattened interfluve overlooking the right (northeastern) slope of the valley.

This interpretation is in agreement with that of Williams (1960, 1963) who showed that the Paleozoic surface paleotopography was characterized by a ". . . series of sub-parallel ridges and valleys trending slightly west of north" (p. 14). Thus he distinguishes from west to east - the Edmonton Channel, the Wainwright Ridge and the St. Paul Channel. The Channels were interpreted by Williams as ". . . valleys of Early Cretaceous rivers which drained the country southeast of Edmonton, and flowed northward into the arctic sea" (p. 14).

If one attempts to fit the studied area into the whole central Alberta scheme proposed by Williams, it can be seen that the Bellshill Lake area is situated in the "high" part of the Edmonton Channel, slightly southwest of the Wainwright Ridge and that the valley whose

evidence has been demonstrated in this study seems to constitute one of the upper arms of the Edmonton Channel.

Paleogeology of the Paleozoic Surface

Pre-Mannville paleogeology was compiled from a map published by the Alberta Energy Resources Conservation Board (July 1960 edition) and was transferred to the Lower Cretaceous isopach map in order to show the relationship between paleotopography and paleogeology (see map Fig. 3).

Williams (1960, 1963) showed that the Edmonton Channel was mainly developed in the Devonian Wabamun Formation, and this is the situation in most of the Bellshill Lake area. However, along the main valley which crosses the studied area, the erosion was intense enough to remove the Wabamun carbonates uncovering a wide strip of carbonates and indurated siltstones of the underlying Winterburn Formation.

As the regional dip of Paleozoic strata is very low in the area (2 to 3 degrees to the southwest as compiled from Fig. 3), it seems reasonable to think that lithologic rather than tectonic factors controlled the distribution of valleys and ridges on the Paleozoic surface. Under these conditions, Williams' (1960) remark stating that " . . . the Edmonton Channel developed in carbonates of the Wabamun formation in part due to development of karst features" whereas the ". . . Wainwright Ridge is formed by resistant clastics and carbonates of the Winterburn group", appears plausible.

Nevertheless, it must be kept in mind that these rivers may perhaps have been responsible for the erosion and removal of sediments which were once overlying the Devonian System in this area, namely the

Mississippian, perhaps also part of the Jurassic System and therefore the river beds may have originally lain in formations far different from those in which they may presently be found. Geomorphically the river courses would have shifted with time in response to the resistance of the substrata which were being eroded.

Effect of Paleotopography on Lower Mannville Deposition

An accurate knowledge of the topography of the substratum on which the first Mannville sediments were laid down is important, for this had considerable influence on the nature and the distribution of the deposits.

The first Cretaceous sediments, namely the Deville and Ellerslie Members were first deposited on valley bottoms. These sediments were not of sufficient thickness to smooth out all the topographic irregularities and in one part of the studied area, the overlying "Calcareous" member seems to lie directly on the Paleozoic "highlands". The "Calcareous" member was the last stratigraphic unit to be affected by the pre-Mannville surface paleotopography, deposits of the Fort Augustus Formation being characterized in the whole studied area by lateral continuity and uniformity of thickness.

In order to show the influence of paleotopographic features on Lower Mannville depositional conditions, as well as to reconstitute the geometry of the different stratigraphic units with a maximum of detail and accuracy, a number of stratigraphic cross-sections were constructed using the Base of the Fish Scales marker as datum. These stratigraphic cross-sections, three sub-parallel, roughly oriented SW-NE (Figs. 4, 5 and 6) and one oriented NW-SE (Fig. 7), the location

and orientation of which are shown on the map Fig. 8, will be referred to in Chapter 4, "Stratigraphy".

CHAPTER 4

STRATIGRAPHY

The Mannville Group in Central Alberta

Two transgressions occurred in western Canada during Albian time. The first, beginning in late Early Middle Albian time, was by a boreal sea carrying a fauna indigenous and mainly restricted to western Canada. The maximum southern extension of the seaway occurred during Middle Albian time, after which it retreated northward. The second marine transgression during Late Albian time was by a Gulf of Mexico sea, which eventually united with that of the arctic and expanded into the widespread Upper Cretaceous Colorado sea (Stelck, 1958; Williams, 1960; 1963).

Sediments deposited during the first transgression-regression cycle, prior to the Gulfian transgression, make up the Mannville Group in western Canada. The group is usually underlain in Alberta by Paleozoic strata (Jurassic strata locally) and the top of the group is placed at the base of the black marine Joli Fou shales of the Colorado Group. The Mannville Group, by this definition, includes basal sands of the Gulfian transgression.

The term Mannville (Mannville Formation at that time) was first used by Nauss (1945, 1947). Later, Badgley (1952) raised the Mannville to group status and divided it into three formational units, namely the McMurray, Clearwater and the Grand Rapids Formations. Mellon (1967) suggested not to extend the terms Clearwater and Grand Rapids Formations into Central Alberta and proposed the name Fort Augustus Formation for the upper part of the Mannville Group, above the "Calcareous" member of

the McMurray Formation and below the marine Joli Fou shale.

In central Alberta the thickness of the Mannville Group is highly influenced by the configuration of the underlying Paleozoic surface. Thus in the Bellshill Lake area, the thickness of the Mannville Group varies from 400 to about 610 feet.

The McMurray Formation

The term McMurray Formation was first used by McLearn (1917) in northeastern Alberta to designate bitumen-impregnated quartz sandstones which crop out along the Athabaska River, above Devonian carbonates.

Since then, the name McMurray has been extended to central Alberta to designate a similar succession, essentially detrital, at the base of the Cretaceous. The McMurray Formation is divided into three members, in ascending order: Deville, Ellerslie and "Calcareous" Members. Its thickness, which is related to topography on the Paleozoic surface, varies from 70 to 300 feet in the studied area.

The Deville Member

First used by Badgley (1952), this term was afterwards applied by different authors to erosion detritus developed at the expense of the Paleozoic rocks underlying the Cretaceous beds.

The Deville is generally represented in central Alberta by greenish grey, waxy shales, greenish grey shaly siltstones, argillaceous quartzose sandstones or dark reddish brown shales, which may reach up to 30 feet in thickness. "In distribution, the Deville Member is mainly restricted to low areas on the pre-Mannville surface, and does not form a laterally extensive unit" (Williams, 1960, p. 31).

In this work, the Ellerslie Member - Paleozoic contact was logged and studied in detail (see core descriptions, Appendix C) only in the Tower Killam No. 1 well (5-18-42-13W4) but no deposits attributable to the Deville Member were found in this well. Likewise the examination of electric logs showed no evidence of Deville type facies, except perhaps in the Hudson's Bay Oil and Gas Company Ltd. 14-27-41-12W4 well, where about 20 feet of shaly beds appear between the Ellerslie sandstones and the Devonian carbonates.

The Deville Member is not always readily discernible on logs, and may for this reason be present elsewhere in the Bellshill Lake area "trough".

The Ellerslie Member

The term Ellerslie was first applied by Hunt in 1950 to beds previously referred to as "Basal Quartz"; the type section was chosen in the Imperial Whitemud No. 3 well (12-14-51-25W4).

The Ellerslie Member was completely cored in the Tower Killam No. 1 well (5-18-42-13W4) where its thickness is 104 feet (from 3103 to 3207 feet). Here it is represented by light grey to yellowish grey, silty, quartz sandstones, thinly interbedded with dark grey, micaceous silty shales. Sandstones range from fine grained to very fine grained; grains are subrounded to angular, and sorting is generally poor. Black carbonaceous material is locally abundant, scattered throughout sandstones as well as shales.

It must be noted that the sandstones are distinctly finer grained at the top than at the base. In the Killam No. 1 well, the sandstone is silty to very fine grained at the top, and essentially

fine grained in the middle, whereas the basal 20 feet of the member show the presence of rounded dark shale pebbles, the size of which also decreases upwards (3 to 4 mm at top, up to one inch at base - see core descriptions Appendix C). This last detail will be of importance in the reconstruction of the depositional environment.

The small-diameter core in this well made it difficult to investigate sedimentary structures; it may only be mentioned that cross-bedding seems to be fairly common in the middle part of the member.

An examination of stratigraphic cross-sections shows that the Ellerslie Member is very unevenly distributed within the Bellshill Lake area. Its extent and its thickness are directly related to local topography of the sub-Mannville erosion surface. The Ellerslie Member reaches its maximum thickness (180 to 190 feet in the ancient valley that crosses the studied area, is extremely reduced in the southern part, and is absent in the southwestern and northeastern part of the area (see cross-section II, Fig. 5). Thus the shape of the "sandy" sedimentary body which represents the Ellerslie Member in the Bellshill Lake area, in cross-section resembles a lens whose flat side would be oriented toward the top and convex side toward the bottom, the thickest part corresponding to the axis of the valley eroded in the Paleozoic strata.

However the upper surface of the Ellerslie sandstones does not seem to be as flat as the above comparison might lead one to think. In places, as in sections 11 (Township 40, Range 13 W4) and 23 (Township 41, Range 12 W4), the thickness of the member shows abrupt local variations. The writer is of the opinion that these observed hollows may represent the last positions of the river (or rivers) responsible

for depositing the sandstones. The erosional hollows thus formed were afterwards filled up predominantly with shales of the "Calcareous" member.

No fossils were found in the studied sections of the Ellerslie Member sandstones, which is expectable in view of essentially fluvial conditions under which these sediments seem to have deposited.

Where the Deville Member is absent in the studied area, the Ellerslie Member sandstones lie directly on Devonian carbonates (Wabamun and Winterburn Groups). This contact which corresponds to a sharp lithologic change, may be easily detected in cuttings, cores or electric logs.

The "Calcareous" Member

This term was first used by Glaister (1959) for beds previously referred to as the "Ostracod Zone", Metacypris persulcata zone (Loranger, 1951), or Metacypris angularis zone (Badgley, 1952).

In the Bellshill Lake area, the "Calcareous" member is mainly composed of greyish black, micaceous, pyritic, silty shales, light grey quartz siltstones and some rare fine to very fine grained quartz sandstones. Coal is common, especially in shales, in the form of flecks and streaks, or beds up to several inches thick. Locally thin beds of greenish grey to dark grey cryptocrystalline limestones may be encountered, especially in sections where shales are prominent.

In typical sections of the "Calcareous" member, siltstones are ordinarily not well developed and are mostly rather argillaceous. Quartz grains are generally sub-angular and the sorting is poor.

Carbonaceous material may be locally abundant both in shales

and in siltstones, as is fossil wood (up to several inches long) mainly in siltstones. Gypsum in small crystals was observed in shales of the Hudson's Bay et al. Schultz Lake 4-15-41-12W4 well (see core description - Appendix C).

Cross-bedding may locally be observed, especially at the base of siltstone layers.

The above lithologic description is representative of the "Calcareous" member facies in most of the Bellshill Lake area and particularly in almost all the eastern half of the studied area. It also agrees fairly well with the different authors' descriptions of the member in central Alberta. However, examination of the stratigraphic cross-sections (Figures 4-7) shows that two important features affect the stratigraphy and the geometry of the "Calcareous" member in the region:

(1) in a narrow, roughly NW-SE band, dividing the studied area into two parts, the "Calcareous" member is cut by a thick, massive sandstone section (Fig. 8). This feature has often been associated with the underlying Ellerslie sandstones by the different authors who have studied it. This "Ellerslie" sandstone thickening, referred to as the "Cameron Zone" by Rudolph (1959) was thought to be a sand bar whose build up was caused by the action of local currents (p. 882). On the other hand, Conybeare (1964, 1967) and Martin (1966) considered these deposits to represent eroded fluvial terraces of Ellerslie age. The writer's opinion, supported by geometrical and petrological arguments, is that the feature is not related to the Ellerslie Member, but results from the erosion by a river in early Fort Augustus time.

It is thought that the channel, which erodes deeply into the "Calcareous" member, marks the base of the Fort Augustus Formation in the Bellshill Lake area.

(2) going northwest, the "Calcareous" member, essentially shaly, tends to become coarser with siltstones dominating the sections. It must be noted that the modification mainly seems to affect the upper part of the "Calcareous" member, as electric logs show that the lower part, particularly because of the presence of thin limestone beds, resembles the facies of the "Calcareous" member in the rest of the studied area.

Figure 8 shows the distribution of this coarser detrital facies within the studied area. In the Tower Killam No. 1 well, the facies is composed of light grey argillaceous siltstones, ordinarily very calcareous, thinly interbedded with dark grey, silty shales, locally rich in coaly material.

The thickness of the "Calcareous" member is highly variable within the Bellshill Lake area. In the southern part of Township 40, Range 13, the "Calcareous" member directly overlies the Paleozoic surface, the irregular topography of which controls the thickness of the member in this area. Moreover the "Calcareous" member sediments seem to have filled eroded hollows in the Ellerslie sandstones and because of these two factors, the thickness of the "Calcareous" member ranges from 40 feet to 180 feet in the studied area. It must be noted that in the northwestern part of the studied region where the "Calcareous" member is mostly represented by detrital facies, the thickness is the most uniform - about 100 to 120 feet.

The "Calcareous" member of the Bellshill Lake area is not very fossiliferous, with only a few ostracod and plant remains (see core descriptions, Appendix C) recovered in some of the studied wells. However, numerous forms were recovered by Williams (1960, pp. 34 to 38) in wells situated farther west or north of the studied area (especially in the South Morningside and Bonnie Glen wells, see map Fig. 1) but these were mainly long-ranging species which did not permit assigning a precise stratigraphic age to the member. On the basis of the fossils, Williams (1960) concluded that the McMurray Formation was continental in origin except for the topmost few feet.

Where the "Calcareous" member directly overlies the Paleozoic surface, the base of the member is very distinct as it corresponds to the contact between shales ("Calcareous" member) and carbonates (Devonian). Elsewhere, the contact with the underlying Ellerslie sandstones is gradational and may not always be placed with precision, especially in the northwestern part of the area where the "Calcareous" member is silty.

The Fort Augustus Formation

The name Fort Augustus Formation was first used by Mellon (1967) to describe beds above the "Calcareous" member of the McMurray Formation and below the marine Joli Fou shale in the Central Alberta plains. The name is taken from the Anglo-Canadian Home C. and E. Fort Augustus No. 1 well (7-29-55-21 W4), 25 miles northeast of Edmonton (Fig. 1), where the type section of the formation is present between depths of 2427 and 2900 feet. In the Edmonton area, the base of a persistent glauconitic sandstone named the Wabiskaw Member (Badgley, 1952) marks the lower

contact of the Fort Augustus Formation.

The Fort Augustus Formation is correlative with the type Clearwater and Grand Rapids Formations of the lower Athabaska River area; however, based on faunal, lithological and stratigraphic arguments, Mellon (1967) in contrast with Williams (1960; 1963), considers that these names should not be extended into central Alberta (p. 63).

A number of reasons led the author to adopt the scheme proposed by Mellon (Fort Augustus Formation) rather than Williams' twofold subdivision (Clearwater and Grand Rapids Formations):

- the Clearwater marine influence was rather reduced in the Bellshill Lake area; the Clearwater facies is significantly thinner and contains much less glauconite in contrast to its facies in the Edmonton area.

- the Wabiskaw Member (fully marine) which marks the lower contact of the Clearwater Formation in the Edmonton area is absent in the study area, being represented (or partly represented) by an erosion surface and by significant continental deposits, which means that the simple transgression-regression cycle pattern distinct in the Edmonton area is not as distinct in the study area.

- the Clearwater/Grand Rapids contact is not always readily discernible in the Bellshill Lake area; as this contact is also diachronous it appears preferable to include the beds above the McMurray Formation in a single formation.

In the Bellshill Lake area, the Fort Augustus Formation consists, in ascending order, of:

- grey quartz sandstones and siltstones, inter-

laminated with black silty shales. (Based upon petrological and geometrical arguments these beds are interpreted as river deposits during early Fort Augustus time and are referred to as channel sandstones in this work).

- shales thinly interbedded with siltstones, sandstones or minor limestones, slightly glauconitic (Clearwater facies).

- siltstones and sandstones interbedded with shales and thin coal beds (Grand Rapids facies).

For the convenience in the lithological description of the formation, the following subdivisions are proposed, in ascending order:

- lower part of the Fort Augustus Formation (channel sandstones)

- middle part of the Fort Augustus Formation (Clearwater facies)

- upper part of the Fort Augustus Formation (Grand Rapids facies)

The same subdivision was used in the cross-sections and attempts were made to correlate these units in the study area (see cross-sections Figs. 4 - 7).

Where no channel sandstones occur, the thickness of the Fort Augustus Formation remains relatively constant throughout the studied area at about 330 feet. Where channel sandstones are present, its thickness reaches a maximum of 485 feet.

Lower Fort Augustus Formation

Lithologically the channel deposits, which constitute the lower part of the Fort Augustus Formation, are made up of light grey to greenish grey, quartz sandstones and light grey quartz siltstones, either regularly or irregularly interlaminated (or thinly interbedded) with greyish black to black, micaceous, silty shales. Siltstones are mainly present in the upper part of the channel. Sandstone grain size (ordinarily fine grained) ranges from very fine to coarse, grain shape ranges from sub-rounded to angular (mostly sub-angular), and sorting is generally good. Graded bedding has been noted locally.

In the 3-12-41-12W4 well, siltstones show abundant dark granules of shale, whereas sandstones include irregular bodies of shale in the 1-33-41-12W4 well. Shale pebbles were observed in the lower part of the channel in the 4-32-41-12W4 well, and in the middle part in the 1-33-41-12W4 well; in the 9-15-41-12W4 well, shale pebbles have a diameter of several inches and are very irregularly shaped.

Fossil wood (pieces up to several inches long), as well as coaly and carbonaceous material are common.

In one well (4-32-41-12W4) shales, interlaminated within fine grained sandstone containing coarse to very coarse grains as well as shale pebbles, show dips of about 40° (10° at the base). However, it must be noted that the position of these features is such that they may belong to either the channel sandstone or to the underlying Ellerslie Member.

No fossil remains have been observed in the sediments assigned to the channel, although worm tracks and borings are common.

Cross-bedding has been noted throughout the section in several wells.

The channel crosses the studied area from east to west for about 20 miles (see Fig. 8). Roughly oriented E to W in Townships 40 and 41, Range 11, it shows two sharp elbows, first toward the north and then toward the west again in Township 41, Range 12. The lack of well control in certain parts of the area does not always allow detailed mapping of the channel, but it would appear to be rather meandering. A number of tributary channels seem to be connected with the main channel, with one coming from the northeast in Township 42, Range 12 and one from the southwest in Township 40, Range 13.

The width of the main channel seems to be fairly constant, at approximately one and a half miles. The widening which may be observed in Township 41, Range 12 (2.5 miles) is likely to be related to the meander of the channel at this location.

The base of the channel which corresponds to the base of the Fort Augustus Formation is generally difficult to determine as channel sandstones often rest directly on the underlying Ellerslie sandstones. However, the contact seems to be marked on electric logs in some wells by the presence of more shaly beds (presence of shale pebbles?) in the sandstone section. Thickness of channel deposits appear to reach a maximum of 150 feet (see cross-sections III and IV, Fig. 6 and 7). It is on the edges of the channel and in the eastern part of the studied area where the channel cuts the shaly facies of the "Calcareous" member that its thickness may be determined most accurately; in fact, in several wells, shales of the "Calcareous" member appear below the channel sandstones (see electric log, Fig. 9). On the other hand, the upper surface

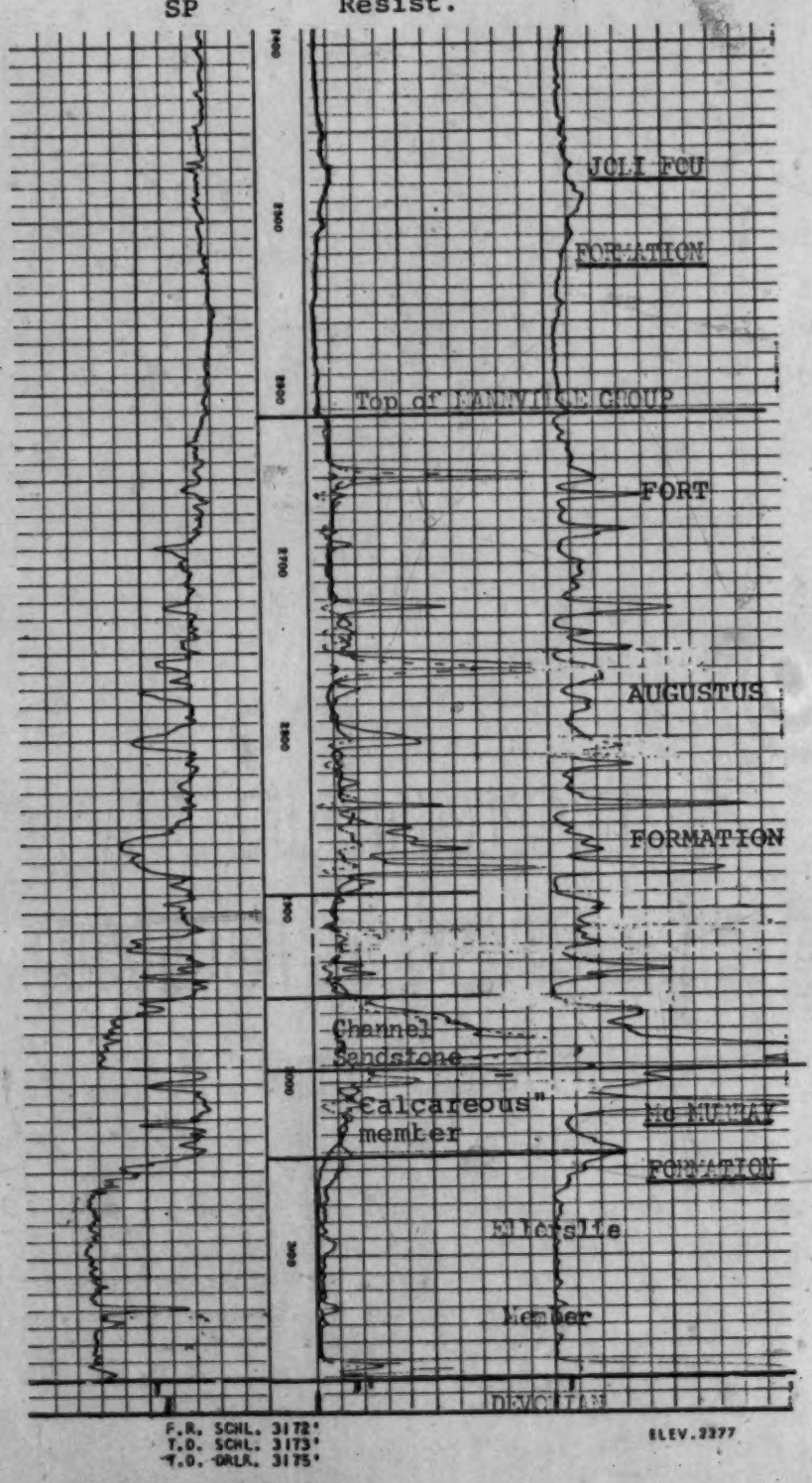


FIGURE 9

RICHFIELD HUDSON'S BAY BOLDT N°7-8 (7-8-42-12W4)

Electric log showing "Calcareous" member shales below the channel sandstone

of the channel deposits is generally well marked as it corresponds to the contact between a massive sandstone section and shales or shales thinly interbedded with minor siltstones and sandstones.

Middle Fort Augustus Formation

The lowermost beds of the unit (lower 30 feet), referred to as the Clearwater facies, are composed of light grey, quartz siltstones or sandstones, usually slightly glauconitic, interlaminated or thinly interbedded with light grey to dark grey, micaceous, pyritic shales, locally rich in coal partings. Shales are also slightly glauconitic locally especially in the lowermost beds of the formation. Thin, bluish grey sub-lithographic limestone beds may locally be present as in the 4-15-41-12W4 well.

Grain size ranges from silt to fine sand, grain morphology from angular to sub-angular and sorting varies from good to very poor.

Long pieces of fossil wood as well as carbonaceous material in nodules up to half an inch in diameter were observed in the 10-32-41-12W4 well. Black coaly material is common throughout siltstones or sandstones. Sparse worm borings were also observed.

A thin glauconitic siltstone or sandstone layer (10 feet thick) located, where no channel sandstones occur, about 20 feet above the lower contact of the Fort Augustus Formation correlates over most of the study area (see cross-sections Fig. 4-7). This sandstone is distinctly thinner (10 feet versus 30 to 60 feet), contains much less glauconite and is carbonaceous in contrast to the Wabiskaw Member in the Edmonton area (Williams, 1960). Since this sandstone is also located 20 feet above the base of the Fort Augustus Formation as defined in this study,

it is thought that the Wabiskaw Member of the Edmonton area is represented here by the erosion surface beneath the channel sandstones whereas the glauconitic sandstone in the study area may be chronologically correlative with one of the glauconitic sandstones considerably above the base of the Clearwater to the northeast (for example the sandstone 130 feet above the base of the Clearwater in the Imperial Eastgate well (1-22-57-22W4) - Williams, 1960 - see Fig. 1).

The uppermost beds of the unit (upper 15 to 30 feet) are composed of dark grey, pyritic, silty shales, thinly interbedded with light grey to dusky yellow, mottled, glauconitic siltstones or sandstones. Sandstones are rather rare; they are usually fine grained to very fine grained and well sorted.

Ostracod remains were recovered at the base of the unit, in shales immediately above the channel sandstones in the 3-12-41-12W4 well, which tends to suggest lacustrine type environment conditions for the lowermost beds of the unit. However, the glauconite content, though reduced in all the remainder of the unit shows that the beds making up the middle part of the Fort Augustus Formation are essentially marine in origin.

The thickness of the unit varies from about 40 to 70 feet in the studied area.

Where channel sandstones occur, the lower contact of the unit is generally well marked as it corresponds to the contact between a massive sandstone section and shales or shales thinly interbedded with minor siltstones and sandstones. Everywhere else the lower contact of the unit which is also the base of the Fort Augustus Formation is difficult to

determine with accuracy as it corresponds to the contact between two predominantly shaly units. However, it must be noted that the contact frequently occurs 10 to 15 feet below the base of a thin siltstone layer (usually less than 10 feet) which correlates over most of the studied area (see cross-sections Fig. 4-7).

Upper Fort Augustus Formation

Due to its low attractiveness from the point of view of petroleum prospects, the upper part of the Fort Augustus Formation, here referred to as the Grand Rapids facies, was only rarely cored in the Bellshill Lake area, and therefore was not studied, other than by reference to the work of others (Williams, 1960, 1963; Singh, 1964; Campbell and Williams, 1965; Mellon, 1967).

In central Alberta it consists of ". . . medium-grained, poorly sorted, iron-stained, feldspathic, 'salt and pepper' sandstones, medium grey, silty, carbonaceous shales and coal" (Williams, 1960, p. 42).

In the study area, electric logs show the upper part of the Fort Augustus Formation to be mainly composed of resistive, thus probably fairly calcareous, siltstones and sandstones, interbedded with shales. In the northwestern part of the area, siltstones and sandstones seem to predominate in the lower portion of the formation, whereas shales are prominent in the upper portion; this does not seem to apply over the remainder of the region.

The thickness of the upper Fort Augustus is relatively constant throughout the Bellshill Lake area - about 300 feet. Minor variations seem to be due to differential compaction phenomena.

Fossil remains are usually not abundant, and this unit is considered

to have been formed mainly in non-marine deposition environments (Singh, 1964).

The upper contact of the unit corresponds to the upper limit of the Mannville Group; the disconformable contact being located at the base of the dark marine Joli Fou shales, which mark the return of the sea in the region.

Age and Correlation of the Mannville Group

On paleontological evidence, Mellon and Wall (1956) and Williams (1960; 1963) assigned a Lower Albian age to the uppermost McMurray Formation, but the lack of index fossils did not allow them to ascribe a precise age to the lower part of the formation. "The lower beds of the McMurray Formation may be as old as Aptian, but in the writer's opnion the evidence is inconclusive. Part of the McMurray Formation (i.e. the Deville Member) is probably as old as Jurassic" (Williams, 1960, p. 53).

A study of the Mannville microflora enabled Singh (1964) to show that the base of the Mannville Group in east-central Alberta was not older than late Barremian. "The microflora of the basal Deville Member is dated as late Barremian, and that of the overlying Ellerslie Member as Aptian" (Singh, 1964, p. 1).

The upper Mannville Group is easier to date. Both the fauna (Stelck et al., 1956, Williams, 1960) and the microflora (Singh, 1964) indicate a Middle Albian age for the Fort Augustus Formation.

Therefore it seems possible to summarize the ages presently attributed to the different stratigraphic units of the Mannville Group as follows:

Fort Augustus Formation		Middle Albian
	"Calcareous" Member	- Lower Albian
McMurray Formation	Ellerslie Member	- Aptian
	Deville Member	- Late Barremian

CHAPTER 5

PETROLOGY OF THE SANDSTONES

Size Analysis

Nineteen samples from the McMurray Formation and the channel sandstones of the Fort Augustus Formation were analysed in order to get an approximate idea of the grain size distribution, to attempt an environmental recognition, and see if the stratigraphic units could be distinguished by this method. Seven of these samples could not be assigned to specific units with confidence because of their location in sections. Distribution of samples is as follows (location of samples - Appendix B):

Channel sandstones	= 9 samples
"Calcareous" member	= 1 sample
Ellerslie Member	= 2 samples
Ellerslie or Channel sandstones	= 7 samples

Sandstones were disaggregated in a mortar, using gentle pounding with a porcelain pestle. Samples were then examined with a binocular microscope to check that aggregates were completely destroyed.

Oil was removed from highly oil stained samples using a Soxhlet extractor with acetone as solvent. Average treatment time for one sample was about 8 hours and results were quite satisfactory for the intended purpose.

Sieving was accomplished using a 0.25 Ø screen interval (-1.0 to 4.5 Ø set) on a Ro-Tap shaker for twenty minutes.

The data obtained (weights of different fractions) were processed on the IBM 360/67 computer of the University of Alberta Computing Center, using a program written for the Department of Geology, to deter-

mine statistical parameters and plot the main size distribution curves of the sediments.

The mode, median, mean, standard deviation, skewness and kurtosis were calculated by the method of moments. The computer also gave the percentage of silt, clay and sand and for each sample plotted the histogram, the frequency curve and the cumulative curve on probability ordinate.

The statistical parameters computed have been summarized on Table II, and cumulative curves are shown on Fig. 10 (Ellerslie and "Calcareous" members) and Fig. 11 (Channel sandstones). Calculated statistical parameters were plotted by stratigraphic unit (Fig. 12) to see whether distinctions were apparent. Cross-plots of all combinations of mean, standard deviation, skewness and kurtosis were also constructed (Fig. 13). In all cases, the ranges of values encountered and extent of mutual overlaps made it impossible to draw any definite conclusions from the results, although the following general observations may be made:

1. Silt content is highest in the single sample from the "Calcareous" member (11.4%) and sample C 12 from the top of the channel deposits in the 13-22-41-12W4 well (37.8%). (This latter sample is also anomalous in terms of the other parameters and was not included in the calculation of average values given in Table II). The samples of undetermined origin (labelled "unknown" on Fig. 12 and 13) exhibit the lowest values of silt content.

2. The "unknown" samples are slightly coarser-grained (lower values of mode, mean and median) and are somewhat more fine-skewed (higher skewness values) than other samples.

Table II

Size Parameters of Mannville Sandstones

	Ellerslie Member		"Calc" Mb.	Channel sandstones										Ellerslie Member or Channel sandstones					
	R_{51}	R_{66}	I_5	D_9	D_{13}	D_{15}	E_{13}	G_8	G_{10}	L_{23}	M_{19}	C_{12}	O_9	O_{12}	O_{22}	O_{26}	P_7	P_{14}	P_{15}
Silt content (%)	5.47	5.68	11.38	0.90	2.90	5.55	1.32	1.02	2.08	1.16	7.23	37.84	1.12	1.72	0.95	0.73	9.47	1.14	0.55
	Avge= 5.57			Average = 2.76										Average = 2.24					
Sand content (%)	94.53	94.32	88.62	99.10	97.10	94.45	98.68	98.98	97.92	98.84	92.77	62.16	98.88	98.28	99.05	99.27	90.53	98.86	99.45
	Avge= 94.42			Average = 97.23										Average = 97.76					
Mode (ø)	3.12	2.37	2.87	3.12	2.62	3.12	2.87	2.62	2.87	2.87	3.12	3.87	2.62	2.62	2.12	2.37	2.37	2.37	2.37
	Avge= 2.74			Average = 2.90										Average = 2.40					
Mean (ø)	3.14	2.58	2.68	2.93	2.69	3.12	2.81	2.72	2.76	2.84	3.10	3.67	2.64	2.53	2.19	2.45	2.65	2.51	2.34
	Avge= 2.86			Average = 2.87										Average = 2.47					
Median (ø)	3.15	2.52	2.64	2.98	2.66	3.12	2.84	2.73	2.75	2.84	3.08	3.82	2.63	2.46	2.18	2.46	2.47	2.46	2.34
	Avge= 2.83			Average = 2.87										Average = 2.43					
Standard Deviation (ø)	0.59	0.76	0.94	0.44	0.54	0.60	0.42	0.44	0.47	0.39	0.51	0.92	0.47	0.53	0.50	0.51	0.83	0.41	0.40
	Avge= 0.67			Average = 0.46										Average = 0.52					
Skewness	-0.46	0.59	0.55	-1.00	0.56	-0.48	-0.22	0.06	0.56	0.43	0.74	-1.39	0.37	1.07	0.75	0.32	0.74	1.68	0.71
	Avge= 0.06			Average = 0.32										Average = 0.80					
Kurtosis	5.06	4.28	3.36	7.80	7.56	5.94	8.49	6.40	6.86	7.72	5.02	4.82	5.70	6.10	8.26	4.71	3.66	10.20	8.33
	Avge= 4.67			Average = 6.97										Average = 6.70					

For origin of samples (Well No.) see Appendix B.

Figure 10.

CUMULATIVE FREQUENCY CURVE ON NORMAL PROBABILITY ORDINATE

Ellerslie and " Calcareous" Members

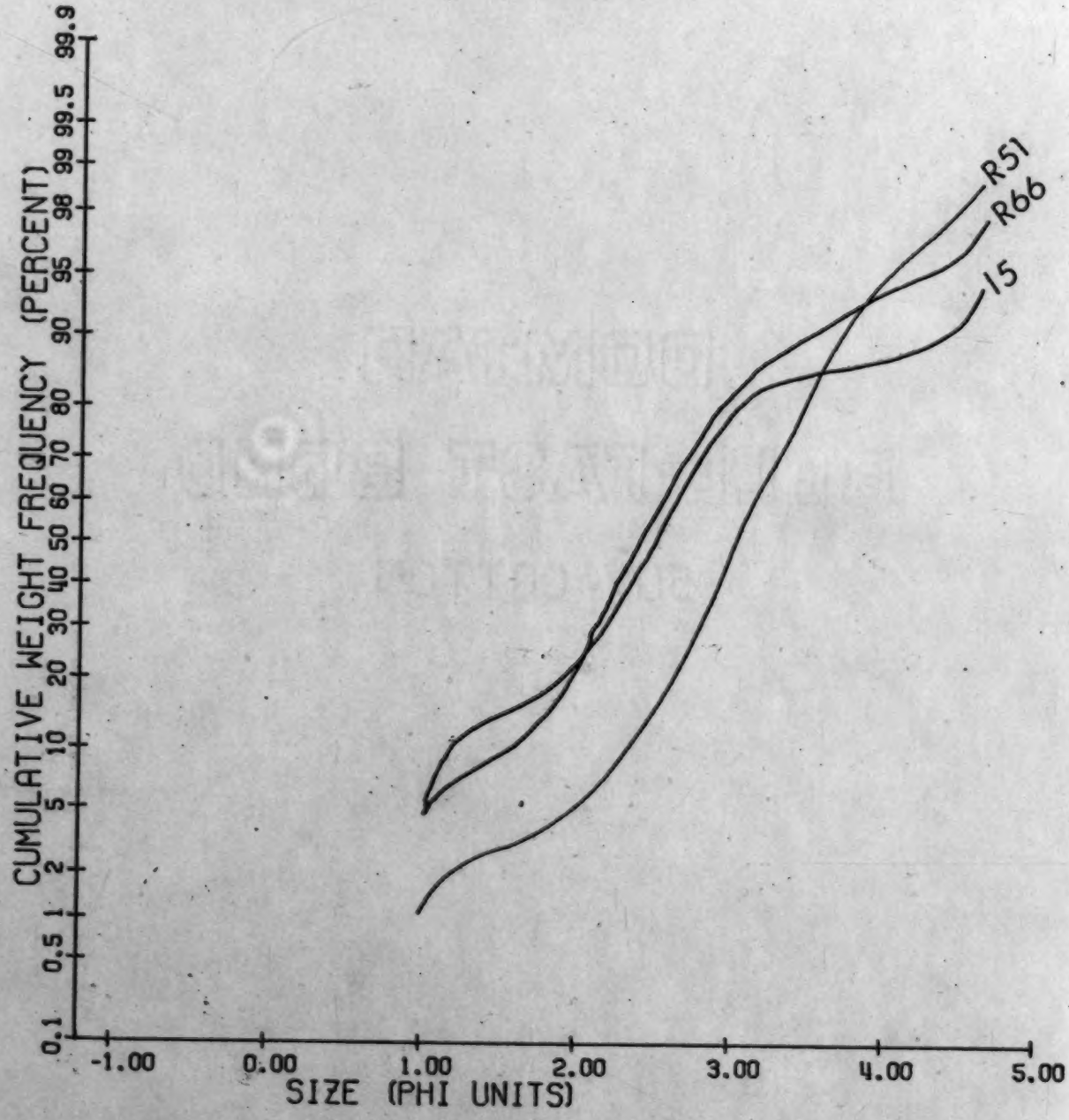


Figure 11.

CUMULATIVE FREQUENCY CURVE ON NORMAL PROBABILITY ORDINATE

Channel Sandstones

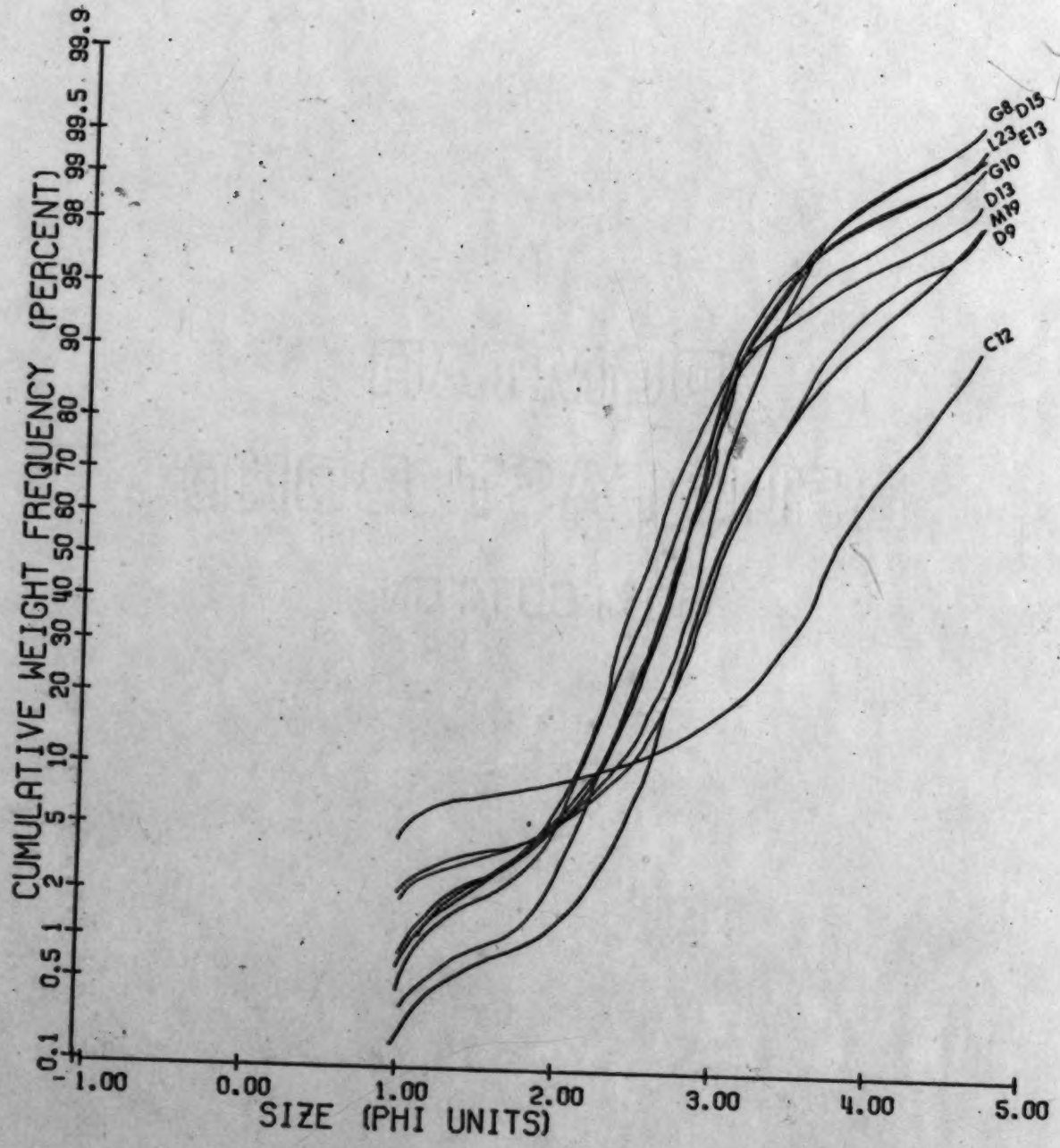
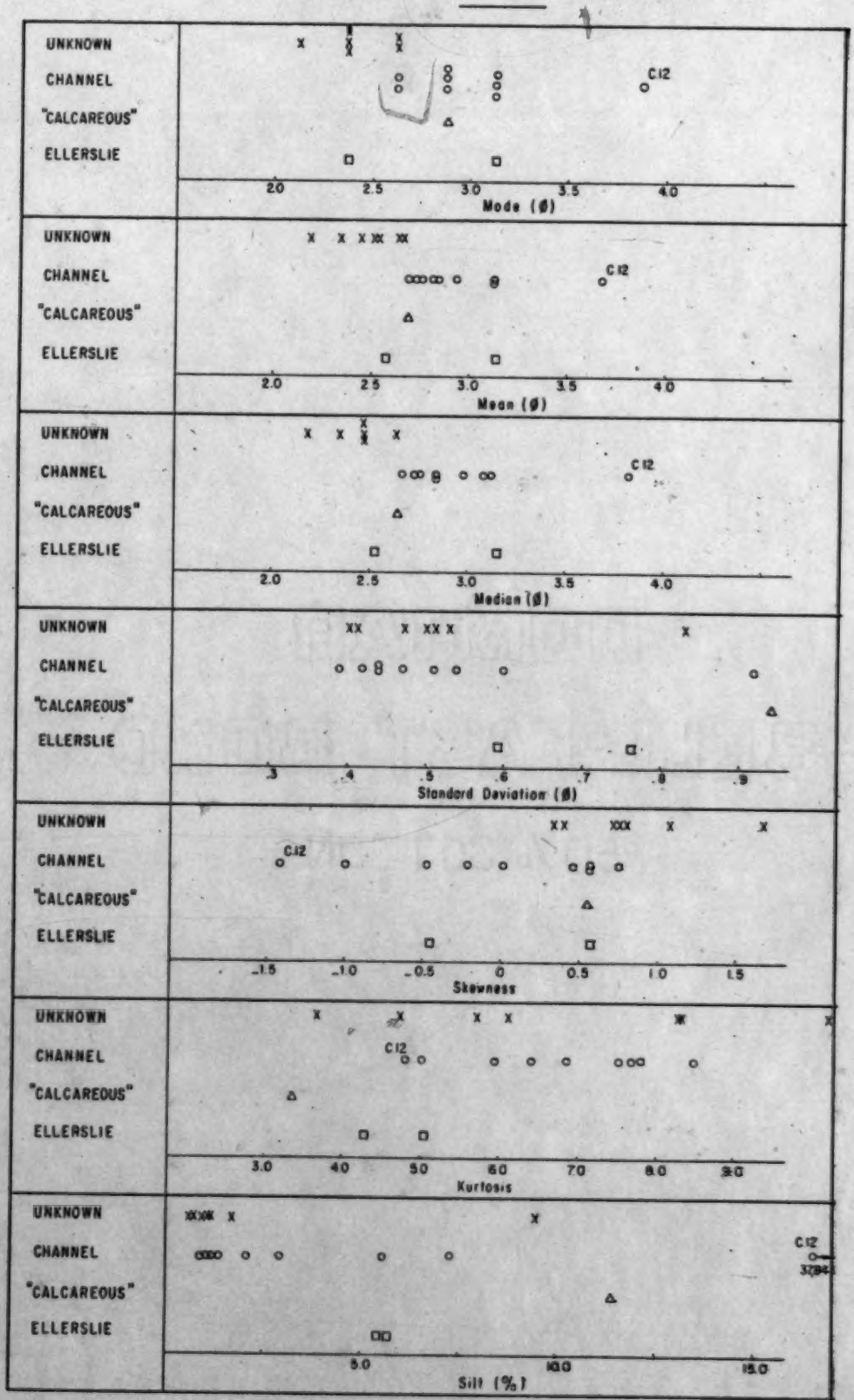


Figure 12

PLOT OF STATISTICAL SIZE PARAMETERS VERSUS STRATIGRAPHIC LOCATION OF SAMPLES



Several authors, notably Friedman (1961, 1962, 1967), and Moiola and Weiser (1968) have demonstrated correlations between size frequency distribution and depositional environments. Only provisional rules have been established however and numerous exceptions to these rules have been observed. Superimposed upon the cross-plots of Fig. 13 are the lines which are supposed to separate different depositional environments according to these authors. As is apparent from the figure, depositional environments of the samples analyzed in this study cannot be differentiated on the basis of the empirical "rules" suggested by Friedman and Moiola and Weiser.

Composition of the Sandstones

Material and Procedure Used

A total of 50 thin sections of the McMurray and Fort Augustus Formations were prepared. Their stratigraphic distribution is as follows (see also Appendix B):

Fort Augustus Formation (Middle Part)	= 6 thin sections
Channel sandstones	= 29 thin sections
"Calcareous" member	= 8 thin sections
Ellerslie Member	= 3 thin sections
Ellerslie Member or Channel deposits(?)	= 4 thin sections

Because of the high degree of friability of most of the studied sandstones, about half of the samples had to be solidified by injection of resin before thin sections could be prepared. This substance has the disadvantage of "darkening" the thin sections however, and has sometimes made difficult the examination and determination of matrix.

Most of the thin sections were etched with hydrofluoric acid fumes for thirty seconds and stained with a concentrated sodium cobaltinitrite solution (Hayes and Klugman, 1959). After this treatment

K-feldspars are stained yellow, whereas plagioclase appears milky white from the etching.

The point count method was used to analyze twenty thin sections whose stratigraphic origin is indicated in Tables III and IV. Two hundred and fifty points were determined using a spacing of 0.2 mm. They were classified as quartz, rock fragments, feldspars, matrix, cement, accessories and pore space. As shown on Tables III and IV where the data as well as the calculated percentages have been summarized, a certain number of supplementary subdivisions were also made, e.g. rock fragments include chert, mud-rock fragments, and metamorphic rock fragments.

Most of the petrographic properties of sandstones have already been reviewed, notably in the lithologic description of units (Chapter 4 - Stratigraphy). These characteristics will not be dealt with again here; they have been summarized in Table V along with the main compositional characteristics of the sandstone.

Composition of Ellerslie Sandstones

Ellerslie sandstones are characterized by their high quartz content (56% to 83%), and their low feldspar and rock fragment content (respectively 1.2% to 2.0% and 1.2% to 2.4%). Matrix percentage ranges from 1.2% to 8.3%. Sandstones are often cemented, essentially by calcite; the percentage of calcite reaching a high of 40% in one of the thin sections (R83). Accessory minerals recorded are muscovite and tourmaline. Pore space percentage varies from 0 to 8.0%. However, owing to the high degree of friability of most of the samples and the treatment to which certain samples were subjected, only limited reliability may be

Table III - Composition of Sandstones of McMurray and Fort Augustus Formations in Volume Percent

Sample No.	Ellerslie Mb.			"Calcareous" Mb.					Clearwater facies		
	R_{72}	R_{81}	R_{83}	I_9	B_5	B_{21}	K_{19}	R_{20}	R_8	I_1	J_6
Quartz	83.2	77.0	56.0	60.0	76.2	61.2	47.2	60.0	44.4	64.4	54.4
K-Feldspar	1.2	1.6	0.8	2.4	0.4	3.2	2.0	P	1.6	6.4	P
Plagioclase	0.8	0.4	0.4	P	1.2	0.4	-	2.0	2.4	0.4	2.8
Total Feldspar	2.0	2.0	1.2	2.4	1.6	3.6	2.0	2.0	4.0	6.8	2.8
Chert	1.2	1.6	1.2	4.8	5.6	2.8	4.0	4.8	6.8	6.0	6.8
Mud-rock fragments	-	-	-	-	2.8	0.8	2.4	-	-	1.6	1.6
Metamorphic rock fragments	0.4	0.8	P	3.6	4.8	-	3.2	2.0	7.6	7.6	3.2
Total Rock Fragments	1.6	2.4	1.2	8.4	13.2	3.6	9.6	6.8	14.4	15.2	11.6
Matrix	5.2	8.3	1.2	28.8	8.2	12.8	12.8	21.2	32.8	9.6	11.2
Silica	-	2.8	-	P	P	P	P	P	P	P	P
Calcite	-	P	40.0	-	-	18.8	28.0	10.0	2.0	2.8	20.0
Total Cement	0.0	2.8	40.0	0.0	0.0	18.8	28.0	10.0	2.0	2.8	20.0
Muscovite	P	P	0.4	P	P	P	-	P	P	P	P
Tourmaline	-	P	-	-	-	-	-	-	-	-	-
Zircon	-	-	-	P	0.4	-	-	P	P	-	-
Glauconite	-	-	-	-	-	-	-	-	1.2	P	P
Total Accessories	0.0	0.0	0.4	0.0	0.4	0.0	0.0	0.0	1.2	0.0	0.0
Pore space	8.0	7.5	0.0	0.4	0.4	0.0	0.4	0.0	1.2	1.2	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Recalculation for classification											
Quarts	96	94	96	85	83	90	80	87	71	75	79
Feldspar	2	3	2	3	2	5	4	3	6	8	4
Rock Fragments	2	3	2	12	15	5	16	10	23	17	17
Total	100	100	100	100	100	100	100	100	100	100	100

"P" = present in trace amounts

Note: Owing to the number of points determined (250), the accuracy of the tabulated data is only apparent. One point is equal to 0.4 percent, and this decimal is used only for convenience in calculations.

Table IV - Composition of Channel Sandstones and Ellerslie or Channel Sandstones in Volume Percent

	Channel sandstones						Ellerslie Mb or Channel sandstones		
	J_{42}	A_{17}	E_{17}	E_{20}	M_{42}	L_{26}	O_4	P_5	P_{16}
Quartz	32.8	64.8	62.0	58.4	58.4	71.2	68.0	63.6	63.2
K-Feldspar	1.2	0.4	0.4	-	0.8	0.4	0.8	0.4	P
Plagioclase	1.2	0.4	P	0.8	0.8	0.4	0.4	0.4	-
Total Feldspar	2.4	0.8	0.4	0.8	1.6	0.8	1.2	0.8	0.0
Chert	2.4	5.2	6.0	6.8	6.4	6.0	1.2	3.6	2.0
Mud rock fragments	-	0.4	-	0.8	-	0.8	1.6	0.4	-
Metamorphic rock fragments	1.2	1.6	0.4	-	1.6	0.4	0.8	-	-
Total Rock Fragments	3.6	7.2	6.4	7.6	8.0	7.2	3.6	4.0	2.0
Matrix	33.6	2.8	0.8	2.4	30.4	0.4	7.2	0.8	0.0
Silica	-	-	P	P	P	P	-	-	-
Calcite	26.4	-	3.2	28.4	-	-	17.2	30.0	-
Total Cement	26.4	0.0	3.2	28.4	0.0	0.0	17.2	30.0	0.0
Muscovite	0.4	P	-	0.8	0.4	-	0.8	P	-
Tourmaline	0.4	P	P	-	-	P	P	-	0.4
Zircon	-	-	-	-	P	P	-	-	0.4
Glauconite	-	-	-	-	-	-	-	-	-
Total Accessories	0.8	0.0	0.0	0.8	0.4	0.0	0.8	0.0	0.8
Pore space	0.4	24.4	27.2	1.6	1.2	20.4	2.0	0.8	34.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Recalculation for classification									
Quartz	85	89	90	87	85	90	93	93	97
Feldspar	6	1	1	1	2	1	2	1	0
Rock Fragments	9	10	9	12	12	9	5	6	3
Total	100	100	100	100	100	100	100	100	100

"P" = present in trace amounts.

Note: Owing to the number of points determined (250), the accuracy of the tabulated data is only apparent. One point is equal to 0.4 percent, and this decimal is used only for convenience in calculations.

Table V - Summary of main petrographic and compositional characteristics of sandstones of the McMurray and Fort Augustus Formations

Petro. Char. / Strat. Units	Color	Particle Size Wentworth's Scale	Sorting	Particle Morphology Powers, 1953 Roundness	Particle Morphology Powers, 1953 Sphericity	Essential Components Nature - Percentage	Matrix* Nature - Percentage	Cement* Nature - Percentage	Accessory Minerals
Ft. Augustus Fm (lower part)	light grey to dusky yellow mottled	silt to fine grained	well sorted	angular	high sphericity	Quartz = 44 to 64% Feldspars = 4 to 7% Chert and Rock fragments = 11 to 15%	Clay, iron oxide, bituminous material, quartz 9 to 32%	Calcite, silica 2 to 10%	Glauconite Muscovite Zircon
Channel	light grey to greenish grey	silt to coarse grained Locally granules or shale pebbles	well sorted	angular to sub-rounded	low to high sphericity	Quartz = 32 to 71% Feldspars = 1 to 2% Chert and Rock Fragments = 3 to 8%	Clay, iron oxide, bituminous material, quartz 1 to 33%	Calcite, silica 0 to 28%	Muscovite Tourmaline Zircon
Calcareous Mb.	light grey	silt to very fine grained	poorly sorted	angular to sub-angular	low to high sphericity	Quartz = 47 to 76% Feldspars = 1 to 3% Chert and Rock fragments = 3 to 13%	Iron oxide, clay, quartz, bituminous material 8 to 28%	Calcite, silica 0 to 28%	Muscovite Zircon
Ellerslie Mb.	light grey to yellowish grey	silt to fine grained Locally shale pebbles	fairly well sorted to poorly sorted	angular to sub-angular	low sphericity	Quartz = 56 to 83% Feldspars = 1 to 2% Chert and Rock fragments = 1 to 2%	Clay, iron oxide, bituminous material 1 to 8%	Calcite, silica 0 to 40%	Muscovite Tourmaline

*Underlined components are most abundant

attributed to this characteristic.

As recent studies (Blatt and Christie, 1963; Conolly, 1965) have cast doubt on the validity of genetic quartz varieties such as those defined by Folk (1961), no attempt has been made in this study to distinguish genetic groups. However, a rapid survey of the samples has shown that the percentages of polycrystalline quartz and quartz grains with strongly undulose extinction were low, ranging from 1% to 5% and 2% to 17% respectively, the remainder being constituted by common quartz, no volcanic quartz having been recorded.

K-feldspar (microcline essentially) is almost twice as abundant as plagioclase. Feldspars seem to be mainly localized in the most fine grained parts of the samples. Thin section R72 shows numerous feldspars weathered to clay (sericite or illite?).

Chert (mainly of the chalcedonic type) accounts for most of the rock fragments and only a few metamorphic rock fragments have been recorded.

Matrix is essentially clay (probably illite), with lesser amounts of iron oxide and bituminous material.

With the exception of thin section R81 where silica cement in appreciable amounts occurs as authigenic overgrowth in optical continuity with quartz grains (Plate I-1), cement in Ellerslie sandstones is mainly represented by calcite (no dolomite was recorded). As in all the other Mannville Group sandstones, calcite always occurs in the form of very fine carbonate "mud", rather than well crystallized sparite. In thin section R83 where calcite cement makes up to 40% of the sample volume, calcite was found replacing quartz grains. Replacement of quartz grains by calcite may be held responsible for the low quartz content

(56%) of this thin section as compared to other sections (77% and 83%).

Composition of "Calcareous" Member Sandstones

Sandstones of the "Calcareous" member are characterized by a quartz content lower than that of the Ellerslie Member (average 60%), a feldspar content slightly higher (2 to 5%), and rock fragments distinctively higher (5% to 16%). Matrix percentage ranges from 8% to 28%. Sandstones are frequently cemented, essentially by calcite, which ranges in percentage from 10% to 28%. Accessory minerals recorded are muscovite and zircon. Pore space was practically non-existent even when calcite cement was absent in the five thin sections examined in detail.

Common quartz predominates (91%) as compared with quartz having strongly undulose extinction (5%) and polycrystalline quartz (4%). Thin needles of muscovite are present as inclusions within quartz grains.

K-feldspars (microcline mostly) seem to be more abundant than plagioclase.

Chert content was higher than other rock fragment content.

Matrix is composed of quartz, clay and iron oxide. When one of these components dominates the matrix, it is iron oxide; when two components make up almost the whole matrix, they are iron oxide and clay. Clay when present is either thinly disseminated within the thin section or gathered in large dark brown "concretions" (Plate I - 5). Bituminous material was also recorded.

Beside authigenic quartz overgrowths, calcite is the only cement which has been observed. Distribution of cement is irregular. In many

thin sections calcite cement is abundant where grains are coarsest and reduced or even absent where very fine grains occur. In a few thin sections calcite was found replacing quartz grains and silica cement (Plate I - 6).

In almost all the thin sections examined, certain components (e.g. chert and rock fragments) are localized in specific areas, or grains are distributed in laminae or cross-laminae as a function of their size (Plate I - 7).

Composition of Channel Sandstones

Channel sandstones are characterized by a relatively low quartz content (32% to 71%), a low feldspar content (1% to 2%), and a relatively high rock fragment content (3% to 8%). Matrix content is either very low (1% to 2%) or fairly high (30%). Half of the thin sections studied in detail were well-cemented; where cement (calcite) is present, its percentage ranges in volume from 3% to 28%. Accessory minerals recorded are muscovite, tourmaline and more rarely zircon. Pore space is closely related to calcite cement content; it is either very low (in the order of 1%) or relatively high (20% to 27%).

As in the "Calcareous" member, common quartz is largely predominant (90%) as compared to grains with strongly undulose extinction (5%) and polycrystalline quartz (5%).

K-feldspars and plagioclase seem to be present in approximately equal amounts in the studied thin sections. Both microcline and orthoclase have been recorded. Albite was identified in thin section

E20. Feldspars in thin section A17 are frequently weathered into clay (sericite, illite?).

Chert (80%) is far more abundant than other rock fragments (20% - mainly mud - and metamorphic rock fragments but carbonate grains have also been recorded). Feldspars, chert and other rock fragments are commonly localized in the same parts of the thin sections.

Matrix components are clay, iron oxide, quartz and bituminous material. The volume of matrix was found to be either very low (1% - 2%) or very high(20%) and this characteristic does not seem to be linked to the presence or absence of calcite cement. Sometimes matrix composed of clay, iron oxide and quartz makes up thin laminae (section N42, Plate I - 8). In another case, matrix essentially composed of clay forms very thin films around quartz, rock fragments and feldspar grains (section J42, Plate II - 1).

Although silica cement is almost always present as authigenic quartz overgrowths, calcite, whose content ranges from 0 to 28%, constitutes the predominant cement. In most of the thin sections examined it was found replacing essential components. Calcite often seems to have replaced silica cement and percentages of the latter are perhaps far below original amounts. Replacement phenomena may have been extensive in certain areas where calcite makes up large patches; in these areas skeletons of grains which have been replaced may often be seen (Plate II - 2). Extensive replacement may be responsible for the low quartz content in thin section J42.

Although laminae may be observed in certain thin sections, most of the thin sections examined were far more homogeneous than those from other stratigraphic units (Plate II - 4).

Composition of Middle Fort Augustus Sandstones

Sandstones from the middle part of the Fort Augustus Formation (Clearwater facies) exhibit a low quartz content (44% to 64%), a relatively high feldspar content (4% to 7%) and a high rock fragments content (11% to 15%). Matrix content is also fairly high (9% to 32%) whereas cement, though always present and ranging from 2% to 20%, seems to be far more reduced in volume than in Lower Mannville units. Accessory minerals recorded are muscovite, zircon and especially glauconite. Pore space was found to be almost nil (0 to 1%).

K-feldspars (orthoclase and microcline) and plagioclases seem to be present in almost equal amounts. They were fairly often found to be weathered into clay and were sometimes, for this reason, hard to distinguish from matrix clay.

In contrast with the stratigraphic units described above, rock fragments (essentially metamorphic rock fragments) show on the whole a percentage slightly higher than that of chert (mostly cryptocrystalline and microgranular chert).

Matrix is essentially composed of clay (presumably illite). Iron oxide, quartz and bituminous material are also present but far less abundant.

Although authigenic quartz overgrowths are always present, silica cement is in fairly minor amounts as compared to calcite cement. However only in thin section J6 did calcite cement show an important percentage. Calcite, where present in significant amounts, was found to replace quartz grains extensively.

Texture of Mannville Sandstones

The sandstones analyzed, though relatively different from one stratigraphic unit to the other, exhibit a certain number of common features which deserve a few remarks.

Their petrography shows features of sandstones which have never undergone deep burial. This fact was already pointed out by Williams (1960). The most noticeable features that he pointed out were: the friability of the sandstones, the presence of the authigenic quartz overgrowths, the preponderance of tangential inter-grain contacts and the lack of carbonate cements. The author generally agrees with most of these arguments, but the present study seems to disprove the last feature presented (lack of carbonate cement). Finally it should be added that none of the criteria presented by Taylor (1950) for the recognition of the effect of pressure on sandstones, namely the number of contacts per grain, the presence of concave, convex and sutured contacts, and the crushing and yielding of micas, feldspars and rock fragments (p. 716), were studied in the Bellshill Lake area.

Cementation phenomena also deserve additional study. In addition to silica and calcite, a number of other elements play or may play a significant role, for example, clay, iron oxide, bituminous material, feldspars which do not exhibit the rigidity of the unaltered state and "mould" themselves around the nearby grains, and muscovite which because of its plasticity, when compressed between rigid grains, takes a fan-like shape in intergranular spaces (Plate II - 6). Feldspar and muscovite are not normally assigned to the cement class, but components such as clay, iron oxide and even bituminous material, which

have always been classified as matrix in this study, in certain cases could have been classed as cement.

There is evidence that the calcite cement sometimes developed later than silica cement, as calcite locally replaces authigenic quartz overgrowths. It seems difficult however to state that this is the general rule, as it is difficult to determine if carbonate cement is of primary or secondary origin, i.e., if carbonate was brought in solution at the time of deposition (primary cement) or posteriorily to deposition time (secondary cement).

Carbonate may have originated from igneous rock minerals, especially plagioclases but most of it must have come from the weathering and erosion of limestone strata. Water in which the Ellerslie and "Calcareous" members were deposited must have been relatively rich in carbonate, probably from the erosion of Devonian limestones. This was not as likely during Fort Augustus time as most of the Paleozoic strata were covered by Lower Mannville sediments.

Classification of Sandstones

Sandstones classifications have proliferated in the literature, especially during the last two decades and the choice between one or another is sometimes difficult to make. For the purpose of the present study, a compositional classification, that of Travis (1955), was used. The main characteristic of this classification is that chert and quartzite grains are included with rock fragments instead of with quartz.

Figure 14 shows the proportion of essential components (components necessary for the sandstone classification) recalculated to 100

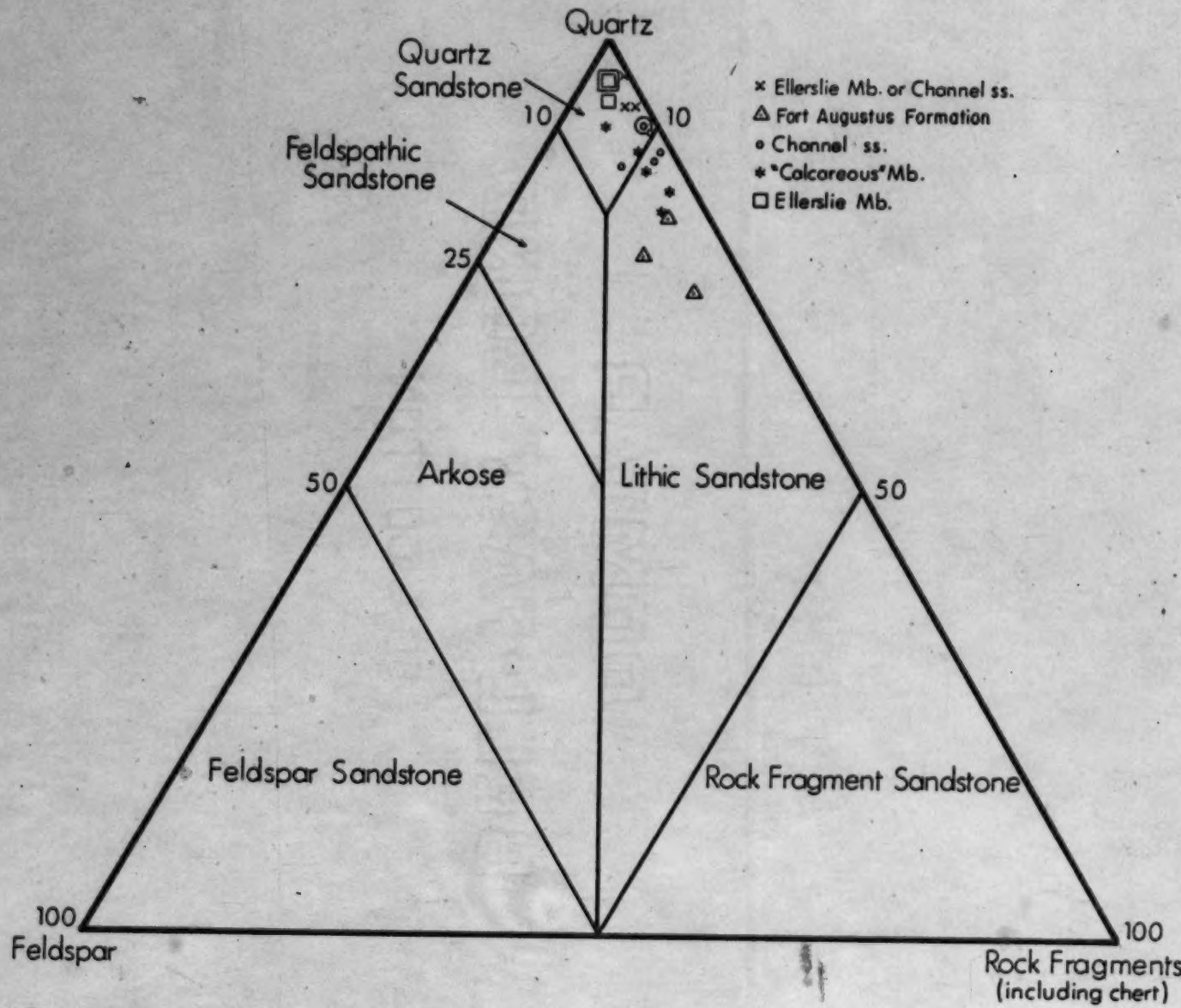


Figure 14- Compositional Classification of Mannville Group Sandstones. (after Travis, 1955)

per cent for each sample (see Tables III and IV). According to Travis' nomenclature, sandstones from the Ellerslie Member are quartz sandstones, "Calcareous" member and channel sandstones are transitional between quartz and lithic sandstones, whereas sandstones from the Fort Augustus Formation are lithic sandstones but with a low rock fragment content.

As for the three samples of undetermined stratigraphic origin, they all are quartz sandstones, but only one of them (P16) is definitely related compositionally to the Ellerslie Member sandstones, the two others are rather transitional between Ellerslie and Channel and therefore may not be assigned with confidence to either of these deposits.

CHAPTER 6

REGIONAL PALEOGEOGRAPHY AND DEPOSITIONAL ENVIRONMENTS

General Statement

The end of the Jurassic and early Cretaceous time corresponded generally in the western Canadian interior to a period of extensive erosion. In the Bellshill Lake area, where the base of the Mannville Group, considered not older than late Barremian (Singh, 1964) directly overlies formations of Upper Devonian age, it is rather difficult to attribute an accurate age to the post-Paleozoic erosional surface. Based on evidence from adjacent areas however, the Mississippian sea (and also the Jurassic sea?), probably spread widely over the region, which reduces somewhat the period during which this erosional surface developed.

Starting probably in late Barremian, the first sediments deposited on the post-Paleozoic erosional surface were continental in origin. Marine conditions developed with the arrival of the Clearwater transgression in Middle Albian time, and when the Clearwater sea withdrew toward the north, continental depositional conditions returned with deposition of the late Mannville sediments.

It is this period stretching from late Neocomian to late Middle Albian time that will be reviewed in the following pages. For each of the stages, an outline of the paleogeography in the Bellshill Lake area will be given, as well as a reconstitution of the local depositional environment. One of the important features underlined in this study, namely the channel which developed during early Fort

Augustus time, will be particularly examined. It will be seen that sedimentation in the Bellshill Lake area has been affected by hydrodynamic, chemical and biological factors, sometimes in multiple combinations.

Neocomian Time

The pre-Mannville erosional surface may have begun to form in late Jurassic time and even earlier; whatever the case may be, it seems that it has to be attributed an essentially Neocomian age. Hydrodynamic factors largely prevailed over the area during this period, and the region was drained by rivers which had a northward orientation and flowed into an arctic sea. In Alberta the former course of these rivers has been reconstituted in detail by Williams (1960) who distinguished from west to east: the Edmonton Channel, the Wainwright Ridge, the St. Paul Channel. Owing to the relatively flat regional dip of the Paleozoic strata on which the rivers were flowing, it seems likely that lithologic factors controlled the distribution of valleys and ridges. Thus Williams' remark stating that ". . . the Edmonton Channel developed in carbonates of the Wabamun formation in part due to development of karst features" (1960, p. 15) appears plausible.

These mature rivers flowed in distinct valleys, the profiles of which as well as of interfluves are very well marked. In the Bellshill Lake area, the riverbed in one of the upper arms of the Edmonton Channel was about 3 miles wide, a fact which may be accounted for by the meandering character of the river course.

The only sediments which were preserved from this period are represented by deposits of the Deville Member, which according to

Singh (1964) might have been formed at the end of Neocomian time (not older than late Barremian in age). These deposits have been noted and described in several regions in Alberta, but were not observed in the study area.

Aptian Time

In the Bellshill Lake area, Aptian time was still dominated by hydrodynamic factors. Chemical factors exercised little influence, being manifested only by local calcification of the sandstones which were laid down during this period, although some of the calcification may also be post-Aptian in age.

The paleogeographic pattern outlined for the Neocomian period remained virtually the same during Aptian time. However the phase of cutting of the river channels was succeeded by a phase of filling up and deposition (Ellerslie Member sandstones). This phase for a river is often to be related with a rise in its base level; in this case it may signify the southward advance of the arctic sea.

The simplest situation implies that filling of the channel was accomplished progressively from bottom to top, however fluvial terraces may have been deposited during the cutting phase of the rivers, and therefore part of the Ellerslie sediments may be pre-Aptian in age. Alternatively positive and negative oscillations of the base level may have developed imbricated terraces of different ages at different elevations, thus it does not seem to be sufficient to consider only the elevation of the different strata in order to attribute relative ages to beds included in the Ellerslie Member, and the absence of fossils in sediments of this type makes paleontological age determination impossible.

In parts of the studied area, the top of the Ellerslie sandstone, ordinarily relatively flat, has been modified, probably by erosion. Erosional activity may have taken place either during the deposition of the "Calcareous" member (the "Calcareous" member shales fill up the hollows thus formed) or in late Ellerslie time. Taking into account the fact that mechanical factors were probably not very intense during the "Calcareous" member depositional processes, the writer feels that the hollows presently observed may be the last channels of the rivers (or river) which deposited the sandstones of late Ellerslie time. The evolution from fluvial to lacustrine environment may have been relatively rapid (the contact between Ellerslie and "Calcareous" members is always quite sharp in these areas) and followed subsequently by the filling in of the channel by predominantly shaly sediments.

These views tend to approximate those of Martin (1966). In his study of the area east of the Bellshill Lake field, namely the Hughenden area, in the same valley, Martin states that ". . . this valley is filled with a thick section of 'Basal Quartz' sandstone beds, which are shaped in several terraces. The terraces . . . were formed by the river cutting down into its own sediments, presumably as a result of the subsidence that affected its source area during Mannville time" (p. 2306). The writer agrees with the idea of a river cutting down into its own sediments and thus leaving the trace of its last location, however, as will be seen later on, the findings of this study do not agree with Martin's views regarding the interpretation of the upper part of the Ellerslie sandstone.

It has already been pointed out that the Ellerslie sandstones

were distinctly coarser at the base than at the top, the size of the elements ranging from one inch diameter shale pebbles at the base to silt at top. Thus the competence of the stream seems to have considerably decreased during the period of Ellerslie deposition, probably in part due to the obstruction of the river bed by transported minerals as a result of a rise in base level. The river must have then occupied a good part of the floodplain with its meanders. This outline of the conditions at the end of Aptian time in the Bellshill Lake area presages the paleogeographic pattern during early Albian time and the probably lacustrine depositional environment under which the "Calcareous" member sediments were deposited.

Albian Time

Albian time in Western Canada is characterized by the invasion of the land by two marine transgressions, the first during Middle Albian, the second during Upper Albian time. Lower Albian time was marked in the Edmonton area by a lacustrine environment, transitional between that of the Ellerslie (continental) and that of the Clearwater (Lower Fort Augustus) which was fully marine.

In the Bellshill Lake area, the "Calcareous" member deposits are also assigned a lacustrine origin, following other authors (Williams, 1960; Mellon, 1967) who dealt with these sediments on a regional scale. In contrast to the Edmonton area, the "Calcareous" member in the Bellshill Lake area does not grade upwards into marine deposits. In fact, early phases of the Middle Albian transgression were only slightly felt in the study area, and the region was still characterized by continental conditions with active fluvial erosion and production of detrital

deposits (channel sandstones). Subsequently, the area experienced a complete transgression-regression cycle in late Middle Albian time.

Lower Albian

The nature of the deposits making up the "Calcareous" member in the Bellshill Lake area (coal-rich shales, carbonaceous material, carbonized wood remains) as well as its fossil remains (freshwater molluscs and arthropods), are in agreement with the essentially lacustrine origin assigned to these deposits by other authors who studied them in Central Alberta (Williams, 1960; Mellon, 1967).

The evolution from a fluvial to a lacustrine environment must have been progressive as attested to by the ordinarily gradational contact between the Ellerslie and the "Calcareous" members, perhaps in part due to the obstruction of the river bed by transported materials, resulting in a decrease of the stream competence. Slight tectonic tilting or damming by sediment . . . could result in the development of large, shallow lakes . . . As the lakes filled with sediment and approached sea level they would provide the appropriate environment for the Ostracod and molluscan fauna of the "Calcareous" member (Williams, 1960, p. 47).

A number of other researchers (Loranger, 1951, and Singh, 1964) suggested that some of the Ostracod fauna of the "Calcareous" member may have developed in fresh or slightly brackish water, such as might be expected in a lake near sea level, or in a brackish environment bordering a source of freshwater or even in fully brackish type of environment. The fact that gypsum crystals were recorded in the 4-15-41-12W4 well in the present study would seem to agree with these views. The cryptocrystalline limestone beds which are interbedded in the "Calcareous" member shales in the Bellshill Lake area suggest that in this sector, during

Lower Albian time, chemical factors (along with biological factors) supplanted hydrodynamic factors which prevailed over the region since early Cretaceous.

To a large extent, the characteristics of lake sediments are determined by the size of the lake, but also by the nature and amount of sediment introduced into it. In the Bellshill Lake area, it is probable that several successive lakes whose location, shape, and characteristics may have changed entirely and very rapidly during the period under consideration received sediment during "Calcareous" member time. Under those conditions it appears relatively difficult to attempt even an approximate reconstitution of the configuration of these lakes. Nevertheless, the presence in the northwestern part of the studied area (see map Fig. 8) of a facies where siltstones are very prominent, as compared to the facies (essentially shales) of the "Calcareous" member in the rest of the region warrants discussion. These sediments in the northwestern part of the area are probably not shore deposits, but they seem to be essentially sheet-like deposits. They more likely represent offshore deposits whose origin might be linked to a local arrival of detrital material coming from the north. A study of the "Calcareous" member in the area stretching north of the studied area would permit the confirmation of this hypothesis.

Middle Albian

Fully continental conditions prevailed again during early Middle Albian time, with the development of the important channel which crosses the Bellshill Lake area as an outstanding feature of the region. Williams (1960) described the channel deposits which occur within the "Calcareous" member west and northwest of Edmonton, and some oil

company geologists showed the occurrence of similar features, though younger, in southern Alberta. To the writer's knowledge channel sandstones have not been reported from the Bellshill Lake area. As several authors have proposed different origins for the deposits in question, careful examination will be given to the different elements which leads to the conclusion that an erosional channel traversed the region in early Middle Albian time.

Late Middle Albian time is characterized by a complete transgression-regression cycle in the Bellshill Lake area, apparently coincident with the maximum extent of the Clearwater sea transgression toward the south, and its subsequent northward retreat in late Mannville time.

Although the marine influence was already evident in the shales immediately above the channel sandstones, the glauconitic siltstones and sandstones mark the beginning of the transgression in the Bellshill Lake area. The thickness of these beds is rather uniform within the studied area, suggesting that the sea transgressed across a rather uniform surface. These beds thus constitute the first stratigraphic unit which was not influenced during its deposition by the Paleozoic paleotopography, although it must be noted that locally, immediately east of the Thompson Lake field, these layers lose their individuality as the usual glauconitic sandstone facies passes into a shaly facies.

According to Williams (1960, p. 49), the next phase of the cycle began ". . . with the period of stillstand at the maximal areal extent of the sea. As the rate of sedimentation increased, sand was deposited across the entire area, the shallow epicontinental sea was filled with

sediment and continental conditions prevailed". Therefore the lower part of the Grand Rapids facies, in gradational contact with the underlying shales is marine, and the beds become progressively more non-marine upward.

The last phase, according to Williams (1960), corresponds to emergence and erosion of previously deposited sediments prior to inundation by the Joli Fou sea. Accordingly, a disconformity has been placed at the top of the Fort Augustus Formation.

CHAPTER 7

CHANNEL SANDSTONES

Introduction

Several authors have described the Lower Mannville of the Bellshill Lake and adjacent areas and discussed the origin of the thick sand section which gives rise to the Bellshill Lake and Thompson Lake fields.

Rudolph (1959), reporting on the Bellshill Lake field discovery in September 1955, stated that ". . . the Basal Quartz sand was probably deposited in a shallow, fresh-water, or at least partly fresh-water, arm of the Lower Cretaceous sea", and that it was ". . . currents which caused the development of the sand bars within the Basal Quartz section of the Lower Cretaceous, such as at Bellshill Lake" (p. 882). This explanation, besides being vague, could not be retained in the present study because the configuration of the thick massive section of the Bellshill Lake area can hardly be incorporated into a "sand-bar" model of a near-shore marine depositional environment.

Conybeare (1964, 1967) and Martin (1966) interpreted the thick sandstones above the Ellerslie Member, in the Bellshill Lake area as being ". . . portions of eroded river terraces in a drowned valley" (Conybeare, 1967, p. 337), thus related to the underlying Ellerslie sandstones. In such an interpretation this feature would have formed in Ellerslie time and would have been surrounded and buried by the "Calcareous" member shales. The writer could not retain this interpretation either; as a matter of fact, it is rather difficult to imagine

a river terrace being eroded in such a regular fashion having an almost constant width. Furthermore these "eroded river terraces", because of the relief that they would have presented, should have influenced the nature and the distribution of the sediments of the overlying "Calcareous" member. It has been shown in this work however that distribution of the "Calcareous" member deposits is quite independent of the distribution of the sediments under consideration and that in fact "Calcareous" member markers, especially in the eastern part of the studied area (detrital facies) correlate across the channel.

Alternative Origins

The interpretations of the sandstones lying above the Ellerslie Member, as being channel-fill deposits is supported by several lines of evidence which will be reviewed further on. Initially, however, other hypotheses were not excluded and were considered.

First of all, it was possible that the sandstones overlying the Ellerslie Member deposits might represent a barrier-island deposit associated with the Clearwater transgression, separating marine deposits in the northwestern part of the studied area (e.g. detrital facies attributed to the "Calcareous" member in this work) from lagoonal type deposits in the eastern and southeastern part of the region (e.g. shales, thin limestone beds attributed to the "Calcareous" member in this work). However the geometrical pattern of these sandstones (see map Fig. 8) is meandering and bifurcating, and cuts across these two facies almost perpendicularly. Besides, the shaly facies of the "Calcareous" member in the Bellshill Lake area is quite similar to that found in other regions of Alberta.

A second possibility was that all the "Calcareous" member in

the northwestern part of the studied area had been eroded by a major river and that the detrital facies that is now found there is associated with the channel deposits proper. This hypothesis has been partly retained since in certain places the thickest sandstone beds at the top of the "Calcareous" member appear to have been incorporated into the channelling pattern. This interpretation has not been generalized to include the whole detrital facies of the "Calcareous" member, as the siltstone layers which form a good deal of this facies northwest of the Bellshill Lake field seem to correlate over several miles, a feature which is not likely to be expected from fluvial-type deposits. From a strictly geometrical point of view, this interpretation would have considerably widened the area of influence of the channel giving it a delta-like appearance on the map, whereas it would be extremely difficult to interpret the deposits in question as delta deposits, both because of their lithologic characteristics and depositional pattern.

Evidence for Channel Origin

There are numerous lines of evidence which strongly suggest a channel origin for the thick sandstone sections in the Bellshill Lake area and their association tends to strengthen the interpretation. These are summarized below.

Bed Continuity

Several siltstone markers in the detrital facies of the "Calcareous" member in the northeastern part of the studied area correlate from one side of the channel to the other. This suggests that the "Calcareous" member was deposited prior to the development of the sandstone which in fact cut through the "Calcareous" member. This

relationship, which may be seen in cross section I (Fig. 4, wells 7-11-41-14W4, 7-10-42-13W4 and 12-13-42-13W4), was central to assigning a channel origin to the anomalously thickened sandstones in contrast to the terrace origin suggested by Conybeare (1964, 1967) and Martin (1966).

Size-Shape

The area occupied by anomalously-thick sandstones in the Bellshill Lake area is narrow and elongate (20 miles long by 1.5 to 2.5 miles wide in the studied area) with a map pattern markedly bifurcating and meandering. The maximum thickness of the additional section, though difficult to determine, seems to be about 150 feet; both the lateral margins and the basal contact are abrupt and probably erosional.

Petrology

Shale pebbles were observed in the sandstone in several wells (4-32-41-12W4, 1-33-41-12W4, . . .) always restricted to the lower half of the section. Shale pebbles are up to several inches in diameter and are very irregularly shaped, suggesting that they were plastic at the time of incorporation into the sandstone, and that they were probably formed very close to where they now occur (Williams, 1966). Bonding agents in the sandstone are a mixture of detrital (clay, bituminous material, iron oxide) and chemical material (calcite essentially). The ratio of grains to matrix is sometimes fairly low (close to 1.0). Fossil wood as well as coaly and carbonaceous material (pieces up to several inches long) are common.

Texture

In all the studied wells, siltstones and shale-beds were

prominent in the upper part of the sandy section, related to a marked upward decrease in grain size from fine and locally coarse grained at base to silt and clay at top; upward-fining graded bedding was locally noted in individual units. Particle shape ranges from sub-rounded to angular but is mainly sub-angular; it is not uncommon to observe fairly well rounded grains included in framework of angular grains. On the whole, however, sorting is generally good, although almost all the samples analyzed for grain size distribution show a marked fine-end tail in the silt range.

Faunal Content

No fossil remains were recovered from the channel fill deposits, although worm tracks and borings are commonly found.

Sedimentary Structures

No ripple marks were observed, but these are not always apparent in cores; cross-bedding however, appears to be quite common. High angle dips (40^{o}) were observed in the 4-32-41-12W4 well but it is not certain that these are not located in the Ellerslie Member sandstones.

These different characteristics have been summarized in Table VI, where they are compared with those usually assigned to fluvial deposits according to Exum and Harms (1968) and Pettijohn et al. (1965).

Summary

These different factors when taken together permitted assigning a channel-fill deposit origin to the sandstones overlying the Ellerslie Member, and were used to map it in the Bellshill Lake area.

Although the channel has been interpreted in this study as

Table VI - Main structural properties and petrographic characteristics of channel sandstones in the Bellshill Lake area as compared to those usually assigned to fluvial deposits

	Fluvial Sandstones After Exum and Harms (1968) and Pettijohn et al. (1965)	Studied Sandstones Bellshill Lake area
Size, Shape, Orientation	Commonly very elongate. Map patterns vary from relatively straight to bifurcating, markedly meandering and anastomosing.	Very elongate Map pattern bifurcating and meandering.
Basal contact of units	Commonly sharply disconformable	Interpreted as disconformable
Lateral margins	Abrupt and erosional	Abrupt and interpreted as erosional
Sorting	Poor to moderate	Generally good
Grain-matrix ratio	Low to moderate	Moderate to high
Cement	Detrital plus chemical*	Detrital plus chemical*
Faunal content	Low to absent (fresh or brackish-water Pelecypods and Gastropods)	No fossil remains observed
Shale pebbles	Abundant	Common
Carbonaceous material	Generally abundant	Common
Internal Organization	Strong asymmetry = upward decrease in grain size and bed thickness, possibly with conglomerate near base	Upward decrease in grain size. Clay content increases toward top. Shale pebbles conglomerate in lower half
Ripple marks	Asymmetrical, abundant	Not observed
Cross-bedding	Abundant. High angle 15°	Common
Beds shape	Tend to be lenticular	Mostly lenticular
"Sole-marks"	Present	Not observed
Other structures	Some tracks and trails	Present

*Detrital cement is approximately equivalent to what is referred to as matrix in this work.

being of fluvial origin, a tidal-estuarine origin should not be ruled out as a possibility. In fact, the presence of worm borings in the sediments and the high degree of sorting in the deposits could be taken as arguments in favour of this alternative interpretation.

The development of a channel obviously implies emergence at the end of "Calcareous" member time perhaps linked to a local uplifting of the region, and initiation of a river which first cut a deep channel, then later filled it up as base level rose with the advance of the Clearwater sea from the north. Lacustrine conditions may have locally prevailed in the region for a short time, as in one place channel-fill deposits are overlain by dark shales from which ostracods have been recovered. Then marine conditions rapidly spread over the area as attested by the presence of glauconite in and beneath a persistent glauconitic siltstone and sandstone layer. Thus the succession of depositional environments in the Bellshill Lake area was apparently fluvial, lacustrine, back to fluvial, lacustrine then marine from Ellerslie to lower Fort Augustus time.

It should be noted that the course of the post-McMurray channel in the studied area is essentially coincident with that of the pre-Mannville valley in which the basal Ellerslie sediments were deposited (see Figs. 3 and 8). At the end of "Calcareous" member time, the Bellshill Lake area was still a depression between the highland areas in the northeastern and southwestern parts of the area (see cross-section III, Fig. 6), and it was in this low area that the early Fort Augustus river developed, in the central part where "Calcareous" member shales were the thickest and compaction phenomena may have already traced a sort of depressed zone.

CHAPTER 8

SUMMARY AND CONCLUSIONS

The main purpose of this work was a petrologic, stratigraphic and paleogeographic study of the Mannville Group in the Bellshill Lake area in order to explain the origin of the anomalously thick quartz sandstones which give rise to petroleum accumulations in the area.

With this aim in view, all the electric logs of wells drilled in a 324 square mile area (nine townships), as well as core samples from sixteen of these wells, were used to provide geometrical, lithological and petrological data on the sediments.

In the Bellshill Lake area the Mannville Group sediments directly overlie Paleozoic rocks (Devonian Wabamun and Winterburn Formations). An isopach map of the Lower Cretaceous strata outlines the paleotopography of the pre-Mannville surface, the major feature of which is the valley of an Early Cretaceous river (and its tributaries), which drained the area south and southeast of Bellshill Lake and flowed northward into an arctic sea.

Beginning in late Barremian time, the first sediments which were deposited on the post-Paleozoic erosional surface were continental in origin (McMurray Formation), and continental conditions prevailed until the onset of the Clearwater transgression in the area in Middle Albian time. Subsequently the sea withdrew toward the north with deposition of the Fort Augustus Formation.

The Deville Member (late Barremian), generally represented in Central Alberta by greenish grey waxy shales and greenish grey shaly siltstones, and usually considered as erosion detritus developed at the

expense of the Paleozoic rocks underlying the Cretaceous beds, was not observed in the Bellshill Lake area.

The Ellerslie Member (Aptian) is represented by quartz sandstones which are distinctively finer grained at the top than at the base (including shale pebbles at base). These sandstones are essentially fluvial type sediments and presumably correspond to the filling-up phase of the Early Cretaceous valleys.

The "Calcareous" member sediments (Lower Albian), mainly shales, were deposited in an essentially lacustrine environment, probably as a result of damming of the river course by sediments. In the northwestern part of the Bellshill Lake area, the "Calcareous" member is represented by a coarser detrital facies consisting predominantly of siltstones. These siltstones, which also seem to be lacustrine in origin, may have been derived from a local source of detrital material located north of the Bellshill Lake area.

Following deposition of the "Calcareous" member, the region became emergent and sediments previously deposited were eroded by a deep river channel, which later filled with sediments, probably following the raising of its base level associated with the advance of the Clearwater sea from the north. The erosion surface at the base of the channel sediments marks the base of the Fort Augustus Formation in the Bellshill Lake area.

The channel-fill sandstones are responsible for the anomalous thickness of the basal sandstones of the Mannville in the Bellshill Lake and adjacent oil fields which most authors have linked to the underlying Ellerslie Member. The channel crosses the Bellshill Lake area from east

to west for about 20 miles, with an average width of about one and one half miles and a depth of up to 150 feet.

Statistical parameters were computed from nineteen sandstone samples which were subjected to size analysis but did not prove useful either in stratigraphic analysis or in determining the depositional environments of the samples studied.

Sandstones of the Ellerslie Member are quartz sandstones, those of the "Calcareous" member and channel are compositionally related and are transitional between quartz and lithic sandstones, while the glauconitic sandstones of the Fort Augustus Formation are lithic sandstones in the terminology of Travis (1955). Most of the Mannville Group sandstones are cemented, essentially by calcite, the main source of carbonate coming from the erosion of Paleozoic limestone beds.

This study demonstrated the presence of channel-fill deposits at the base of the Fort Augustus Formation in the Bellshill Lake area which constitute the reservoir sandstones in the Bellshill Lake and Thompson Lake fields. Additional studies are required to verify the existence of and map the channels over a wider area to add to the knowledge of the depositional history and paleogeography of Mannville time, and as an aid in finding new petroleum accumulations in the Mannville Group.

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APPENDIX A

Names and Locations of Wells Examined

Name and Location	Interval Logged
H.B. et al. Bellshill Lake 3-15-41-12W4	3085-3130
B.H. et al. Schultz Lake 4-15-41-12W4	3045-3135
Banff Champlin Bellshill Lake 8-15-41-12W4	3102-3140
Banff Champlin Bellshill Lake 9-15-41-12W4	3210-3260
H.B. et al. Bellshill Lake 12-15-41-12W4	3059-3103
H.B. et al. Bellshill Lake 13-16-41-12W4	3012-3062
Permo Catalina Bellshill Lake 7-19-41-12W4	3020-3058
Banff et al. Bellshill Lake 6-21-41-12W4	3003-3034
H.B. et al. Bellshill Lake 10-21-41-12W4	3018-3063
Rich. Oil Corp. Bellshill Lake 13-22-41-12W4	2988-2993;3004-3029
Joe Phillips Bellshill Lake 2-27-41-12W4	2970-3012
Rich. Oil Corp. Bellshill Lake 3-28-41-12	2974-3009
Richfield McLennan F 4-32-41-12W4	3056-3081;3096-3160
Richfield McLennan F 10-32-41-12W4	2959-3019
H.B. et al. Bellshill Lake 1-33-41-12W4	2973-3011
Tower Killam #1 5-18-42-13W4	2963-3049;3081-3205

APPENDIX B

Sample Locations

Sample	Well	Approx. Depth (ft.)
Size Analysis		
P7	9-15-41-12W4	3228
P14	"	3254
P15	"	3257
G8	12-15-41-12W4	3071
G10	"	3076
E13	13-16-41-12W4	3045
D9	10-21-41-12W4	3045
D13	"	3052
D15	"	3058
C12	13-22-41-12W4	3013
M19	3-28-41-12W4	3001
O9	4-32-41-12W4	3085
O12	"	3098
O22	"	3132
O26	"	3139
I5	10-32-41-12W4	2975
L23	1-33-41-12W4	3003
R51	5-18-42-13W4	3123
R66	"	3152
Thin Section Analysis		
N11	3-12-41-12W4	3195
N42*	"	3252

Sample	Well	Approx. Depth (ft.)
H14	3-15-41-12W4	3100
H19	"	3111
H27	"	3122
J5 (limestone)	4-15-41-12W4	3052
J6*	"	3053
J35	"	3112
J42*	"	3129
J43	"	3131
F2	8-15-41-12W4	3110
F6	"	3125
F11	"	3140
P5*	9-15-41-12W4	3222
P16*	"	3259
G3	12-15-41-12W4	3060
G7	"	3068
G11	"	3078
E11	13-16-41-12W4	3041
E17*	"	3055
E20*	"	3059
B5*	7-19-41-12W4	3028
B21*	"	3059
A12	6-21-41-12W4	3022
A17*	"	3029
D5	10-21-41-12W4	3030

Sample	Well	Approx. Depth (ft.)
D14	10-21-41-12W4	3052
C6	13-22-41-12W4	3005
C15	"	3019
C23	"	3025
K10 (limestone)	2-27-41-12W4	2992
K19*	"	3010
M6	3-28-41-12W4	2983
M14	"	2995
M20	3-28-41-12W4	3003
O4*	4-32-41-12W4	3065
O19	"	3110
I1*	10-32-41-12W4	2960
I9*	"	2972
I24	"	3008
L11	1-33-41-12W4	2988
L22	"	3001
L26*	"	3005
R8*	5-18-42-13W4	2982
R14	"	3000
R20*	"	3020
R28 (limestone)	"	3028
R72*	"	3170
R81*	"	3201
R83*	"	3204

* Thin sections subjected to point analysis

APPENDIX C

Core Descriptions

Hudson's Bay et al. Bellshill Lake 3-15-41-12W4 (KB 2420)

Core #1: 3085-3097 (rec. 11.8 ft.)

Thickness	Description
1'2"	Sltst., yellowish grey, qtz. with considerable authigenic overgrowth, calc., fairly well indurated, sparse carbonaceous material nodules.
1'1"	Sh., greyish black, with coaly flecks and streaks, glossy, disseminated and finely nodular pyrite is common, minor slickensiding.
1'4"	Sltst., yellowish grey, sl. calc., arg., sl. micromicaceous, well indurated, v. abnt. patchy o.s., xbdg. occurs at base.
0'5"	Coal, and irregularly thinly intbd. glossy black Sh. make up the bed.
4'3"	Sh., med. dk. grey to black, silty dull, abnt. glossy black carbonaceous coaly material, fairly indurated, pyrite either disseminated or forming rods up to half an inch long, intlam. with rare, v. f. lt. coloured Sltst. making up v. thin lentils.
2'9"	Sh., med. grey, silty, carbonaceous flecks and streaks, dull, pyrite common, presence of brown wood remains, partially carbonized or pyritized, intbd. with two seams of black Sh. as above, each 1" thick, at 5" and 1'7" from the top of the int.
0'8"	Sh., dk. grey, silty, glossy, conchoidal broken surface, well indurated, pyrite common, especially in grades up to 1 cm., but also disseminated or in thin rods, thinly intbd. and lam. with Sltst., lt. grey, qtz., indurated, makes up thin lentils, showing in part deformations contemporaneous with the sedimentation.

Core #2: 3097-3130 (rec. 33 ft.)

Thickness	Description
1'10"	Sh., med. dk. grey to greyish black, silty, carbonaceous material common, pyrite v. common especially in nodules, intlam. with lt. coloured Sltst., becoming more prominent at base where they form thin

Thickness	Description
	lenticular beds.
1'6"	S.s., v. f. gr., to Sltst., pale yellowish brown, qtz. with considerable authigenic overgrowth, calc., hard, highly sideritic, siderite forms thin lenticular beds in part, carbonaceous material common, thinly (maximum thickness 3 to 4 mm.) intbd. with black Sh., as above.
4'2"	Sh., lt. grey, micaceous, silty, rare nodules of carbonaceous material, dull, nodules of pyrite common, hard, thinly intbd. at base with lenticular S.s., v. lt. grey, v. f. gr.
4'11"	Sh., med. dk. grey, micromicaceous silty, rare black carbonaceous nodules, dull, nodules of pyrite common, sparse wood fossil remains, hard, thinly intbd. with Sltst., yellowish grey, qtz., micromicaceous material, s.s. becomes prominent toward the base, s.s. seams are 1" to 2" thick at base and include lentils of sh.
3'11"	S.s., v. f. gr., to Sltst., med. bluish grey, qtz., poor porosity, rare vuggy porosity, highly calc., v. hard.
3'8"	S.s., v. f. gr., to Sltst., from yellowish grey to pale yellowish brown, qtz., poor porosity, micromicaceous, scat. o.s., irregularly intlam. with Sh., dk. grey, micaceous, silty, dull, well indurated. Sh. is becoming prominent at base, where it includes v. thin lentils of s.s.
2'10"	S.s. to Sltst., highly calc. as above.
3'9"	S.s., v. f. gr. to Sltst., mod. yellowish brown, qtz. with authigenic overgrowth, A., poorly sorted, good porosity where no authigenic overgrowth occurs, firm, micrmicaceous, mainly scat. o.s. but also some wide heavy oil patches.
4'1"	S.s. to Sltst., highly calc. as above.
1'3"	S.s., mod.yellowish brown, qtz. with sparse authigenic overgrowth, f. gr. to v. f. gr., v. sl. silty, well sorted, a., good porosity, loose, heavy oil saturated.
1'1"	Sh., med. dk. grey, micaceous, silty, glossy, fairly hard, thinly intbd. and lam. with Sltst., yellowish grey, qtz., well indurated, rare scat. o.s., except at 2" thick sltst. seam at 2" from the top of the interval, sltst. beds are usually v. thin and lenticular.

Hudson's Bay et al. Schultz Lake 4-15-41-12W4 (KB2400)

Core #1: 3045-3090 (rec. 44 ft.)

Thickness	Description
3'10"	Sh., dk. grey, silty, smooth broken surface, abnt. nodules of pyrite, hard.
4'6"	Sh., med. dk. grey, micromicaceous, sl. silty, dull, abnt. pyrite either in nodules up to 1 cm. in diameter, or in small 1 cm. long sticks , thinly intbd. or lam. in basal 2' with Sltst., yellowish grey, qtz. with considerable authigenic overgrowth, shaly well indurated, sl. micaceous, sl. glauconitic, pyritic. Sltst. forms. lenticular beds, they are up to 1 cm. thick at base.
0'5"	Ls., med. bluish grey, sub-lithographic, mostly recrystallized, no intercrystalline porosity, very poor vuggy porosity, pyrite common, highly fracturated and filled with Sltst., lt. brown, qtz., sl. calc., loose, abundance of small black nodules (carbonaceous material, o.s.?); the fractures network gives the rock an aspect of pseudo-breccia with big elements.
0'3 1/2"	S.s., greyish orange, qtz. with authigenic overgrowth, v. f. gr., silty, a., fair to poor porosity, calc., shaly, hard, v. irregularly intbd. with Sh., greyish black, silty, dull, pyrite, hard.
0'8"	Sh., greyish black, sl. micaceous, silty and sandy, silty, finely pyritic, lenticularly intbd. with S.s., v. f. gr., to Sltst., v. lt. grey, qtz. with authigenic overgrowth, fair porosity, well indurated, pyritic.
0'3"	Ls., as above.
0'8"	Sh., black, waxy, glassy broken surface, abnt. microgranular pyrite (about 1/20 mm in diameter), thinly intbd. with S.s., dk. yellowish brown, v. f. gr., qtz. with authigenic overgrowth, A., silty, arg., calc., poor porosity due to silt and clay content, hard, scat. o.s.
0'9"	S.s., yellowish grey, v. f. gr., to Sltst., qtz., a., poor porosity, v. calc. well indurated, sl. micaceous, micropyritic, sl. glauconitic, scat. o.s.
0'3"	Sh., black, micaceous, sl. silty, sparkly, pyritic, loose, intlam. with Coal and lenticular S.s., greyish yellow, qtz., v. f. gr., silty, a., poor porosity, sl. calc., hard, abundance of carbonaceous material.
6'10"	Sh., med. dk. grey to med. bluish grey, silty, sl. calc., dull, microgranular pyrite abnt., hard.

Thickness	Description
4'6"	Sh., greyish black, silty, pyrite common, friable, v. f. lam. or thinly intbd. with Coal (coal beds up to 2" thick.
3'5"	Sltst., mod. yellowish brown to yellowish grey, qtz., c., fair porosity, well indurated, micropyritic, micaceous, scat. o.s. varying vertically with grain size, intlam. at base and especially in basal 8" with Sh., dk. grey, micaceous, silty, dull carbonaceous material common, abundance of well defined gypsum crystals, fairly hard.
0'9"	Sh., black, coaly material abnt., glossy, smooth broken surface, fairly hard, intbd., with Coal. Partings of coal are thicker than those of sh.
1'8"	Sh., med. dk. grey, dull, v. abnt. tiny shreds of chlorite (?) giving the rock a greenish color in part, scat. black carbonaceous material, well indurated.
8'10"	Sh., mainly greyish yellow green but also lt. grey to dk. grey, dull, pyrite common, carbonaceous v. abnt. in the dk. grey seams, hard.
6'5"	Sh., dk. grey, sl. micaceous, dull, micropyritic common, intbd. with S.s., yellowish grey, qtz., with considerable authigenic overgrowth, v. f. gr., v. silty, A., fair porosity, calc., sl. pyritic, well indurated, becoming more shaly at base.

Core #2: 3090-3135 (rec. 45 ft.)

Thickness	Description
0'11"	Sh., greyish black, micaceous in part, silty in part, dull to waxy, pyrite common especially in nodules up to 2 cm in diameter, intlam. in part with lt. grey Sltst.
20'3"	Sh., med. dk. grey, micaceous, sl. calc. at base, silty, dull pyrite common either highly dissiminated or in big nodules up to 1", well indurated, intlam. or v. thinly intbd. with Sltst., lt. grey to yellowish grey, qtz. with authigenic overgrowth, c. gr., a., poor porosity, hard, micaceous, sl. o. s. at base.
9'10"	S.s., yellowish grey, qtz. with authigenic overgrowth, v. f. gr., silty, A., fair to poor porosity, well indurated, micaceous, o. s. scat. throughout, thinly

Thickness	Description
	intbd. or intlam. with Sh., med. grey to dk. grey, micaceous, silty, dull, hard, xbdg. in part.
1'2 1/2"	S.s., yellowish grey, qtz., f. gr., a., fairly well sorted, good porosity, sl. arg. in part, sl. calc., firm, pyritic, sideritic.
12'10"	S.s., thinly intbd. or intlam. with Sh., as above. Pyrite common. At 6' from the top occurs a 4" thick seam of v. calc. s.s., med. bluish grey, v. f. gr., r., v. poor porosity, sideritic, v. hard.

Banff Champlin Bell 8-15- 41-12W4 (KB 2431.8)

Core #1: 3102-3140 (rec. 38 ft.)

Thickness	Description
14'0"	S.s., pale olive, qtz., v. f. gr., v. silty, v. poorly sorted, a., poor porosity, firm, micaceous, black carbonaceous material common, intlam. with rare Sh., greyish black to black, silty, glossy, abundance of black carbonaceous and coaly material. But at respectively 4', 6', 6'7", 8' and 14' from the top of the int. (5" thick) sh. seams are as thick as s.s. seams (3-4 mm).
23'0"	S.s., pale yellowish brown, qtz., f. gr., silty, fairly well sorted, a., fair to good porosity, sl. friable, black carbonaceous material common.
1'0"	S.s., pale yellowish brown, as above, intbd. with irregular beds of Sh., dk. grey, micaceous, silky, loose, abundance of coaly and carbonaceous material (pieces up to several inches long).

3-12-41-12R2 (KB 2563)

Core #1: 3183-3223 (rec. 40 ft.)

Thickness	Description
2'6"	Sh., dk. grey, silky, smooth broken surface, pyritic, firm.
7'6"	Sh., dk. grey to greyish black, sl. micaceous, silky, pyritic, some rare black carbonaceous material, firm, intlam. at top and thinly intbd. at base with lenticular Sltst., lt. grey, qtz., well indurated, sl. micaceous, some black carbonaceous material scat. throughout, presence of worm borings.

Thickness	Description
2'6"	Sltst., med. grey, qtz., arg., well indurated, micaceous, abundance of coaly flecks and streaks, thinly intbd. at top of the int. with lenticular partings of Coal.
1'0"	Sltst., yellowish grey, qtz., v. c. gr., a., fair porosity, sl. arg., black carbonaceous material scat. throughout, thinly intbd. with Sh., dk. grey, micaceous, silty, glossy, some thin partings of Coal are also intbd.
0'7"	S.s., lt. olive grey, qtz., v. f. gr., v. silty, v. poorly sorted, a., poor porosity, well indurated, micaceous, thinly intbd. with Sh., greyish black, micaceous, silty, glossy, abundance of black carbonaceous material.
0'11"	Sh., black, silky, abundance of carbonaceous material, loose, thinly intbd. with Coal.
5'0"	Sh., med. bluish grey to dk. grey, silty, dull, black streaks of carbonaceous material common in part, pyritic, firm thinly intbd. with v. irregular lenticular bodies of Sltst., greenish grey, qtz., v. poorly sorted, poor porosity, sl. friable, sl. micaceous, black carbonaceous material scat. throughout.
2'6"	Sh., black, glossy, with coaly flecks and streaks, hard, intbd. with (seams up to 2" thick) of Coal; slickensiding in part.
0'6"	Sh., black, intbd. with Coal, as above.
2'0"	Sh., dk. grey with sl. greenish cast sl. silty, glossy, chloritic (?), hard, thinly intbd. with lenticular Sltst., greenish grey, qtz., well indurated, chloritic (?).
2'6"	Sh., black, sl. silty, dull, abundance of coaly material, sl. loose, intbd. with Coal; coal beds are up to several inches thick, slickensiding in part.
1'11"	Sh., dk. grey, sl. micaceous, dull, fairly well indurated, thinly intbd. (mainly lenticularly) with Sltst., lt. grey, qtz., well indurated, micropyritic.
0'7"	Sltst., lt. grey, qtz., v. f. gr., arg., hard, micaceous, coaly material v. common in part.

Thickness	Description
0'6"	Sh., black, glossy, chloritic (?), pyritic, carbonaceous and coaly material v. common, Ostracod remains.
7'0"	Sh., greenish grey to med. grey, dull, chloritic (?), long streaks of coal in part, hard, thinly intbd., at about 4'0" from the top if the int., with Sltst., lt. grey, qtz., with considerable authigenic overgrowth, sl. friable, micaceous, sltst. include dk. granules of sh. (1-2 mm diameter).

Core #2: 3223-3263 (rec. 32.9 ft.) First box of 8 is missing. Starting at 3228 ft.

Thickness	Description
5'0"	Sltst., med. grey to mod. yellowish brown depending upon o. s., qtz., with considerable authigenic overgrowth in part, v. arg. in part, chloritic (?), micaceous, pyritic, sideritic, not o. s. to highly o. s. depending upon clay content and gr. size.
7'9"	Sltst. med. grey as above, intbd. with S.s., greyish brown, qtz., v. f. gr. to silt, fairly well sorted, r., v. good porosity, friable, heavy o. saturated.
5'0"	S.s., lt. grey to mod. yellowish brown, qtz., v. f. gr. to f. gr., silty, well sorted, a., fair porosity, sl. firable, micaceous, intlam. with rare lenticular dk. Sh.
15'0"	S.s., lt. grey as above, but less silty, good porosity, well indurated, micaceous; black micaceous Sh. on bedding planes.

Banff Champlin Bell 9-T5-41-12W4 (KB 2403)

Core #1: 3210-3260 (rec. 50 ft.) (Due to high disturbance of the core, given thickness will be approximative).

Thickness	Description
2'10"	S.s., greenish grey, qtz., v. f. gr., v. silty, poorly sorted, A., fair to good porosity, sl. loose, micaceous, black carbonaceous material scat. throughout, intlam. with lenticular Sh., med. dk. grey, micaceous, silty, dull, hard.
2'1"	S.s., as above, v. thinly and regularly intbd. with Sh., dk. grey, micaceous, v. silty, dull, firm, abundance of black carbonaceous material.

Thickness	Description
2'6"	S.s., as above, thinly intbd. (or in patches) with lenticular Sh., med. dk. grey, micaceous, silty, dull, rare black carbonaceous material scat. throughout.
1'0"	S.s., lt. grey, qtz. with authigenic overgrowth, f. gr. but presence of rare c. size grains, well sorted, r., poor porosity, v. calc., v. well indurated, micaceous, including numerous very irregularly shaped pebbles of Sh., dk. grey, micaceous, silty, dull, black carbonaceous material scat. throughout, firm.
7'9"	S.s., as above, but rounded, including rare but big rounded pebbles of Sh., as above.
6'3"	S.s., yellowish grey, qtz., f. gr., v. well sorted, a., good to v. good porosity, fairly well indurated, micaceous.
1'3"	S.s., as above, but mottled color, and presence of rare pebbles of dk. grey sh.
15'1"	S.s., lt. grey to mod. olive brown depending upon o.s., f. to v. f. gr., silty in part, fairly well sorted, a., fair to good porosity, arg. in part, friable, micaceous, sparse black carbonaceous material, sl. o. s. in part including v. irregularly shaped pebbles (up to several inches) of Sh., dk. grey, micaceous, firm, long streaks of carbonaceous material.
3'9"	S.s., lt. olive grey to dusky brown, f. gr. with some rare c. grains, silty in part, poorly sorted on the whole, r., fair to good porosity, friable, mostly highly o.s.
7'6"	S.s., yellowish grey, sl. mottled (mod. olive brown), qtz., f. gr., v. well sorted, r., to a., v. good porosity, v. friable.

Hudson's Bay et al.Bellshill Lake 12-15-41-12W4 (KB 2389)

Core #1: 3059-3103 (rec. 19 ft.)

Thickness	Description
0'8"	S.s., yellowish grey, qtz. with authigenic overgrowth in part, v. f. gr., fairly well sorted, sl. silty, A., good porosity in part, sl. loose, v. sl. micromicaceous, irregularly intlam. or thinly intbd. with Sh., dk. grey to black, micaceous, sl. silty, sl. carbonaceous, dull, fairly hard. Some worm borings. S.s. more prominent at top.

Thickness	Description
1'0"	S.s., dusky yellow, qtz. with sparse authigenic overgrowth, f. gr., silty, well sorted, a., good porosity, friable.
0'4"	S.s., as above, but yellowish grey.
0'11"	S.s., mod. yellowish brown, qtz. with authigenic overgrowth, f. gr., v. well sorted, a., v. good porosity where no authigenic overgrowth occurs, friable, o.s.
0'1"	Sh., dk. grey, micromicaceous, silty, dull, fairly indurated, thinly irregularly lam. with S.s., yellowish grey, qtz. with abundant authigenic overgrowth, v. f. gr. to silt, sl. micromicaceous. Abnt. worm borings filled with s.s.
11'11"	S.s., mod. yellowish brown, qtz. with authigenic overgrowth in part, v. f. gr., fairly well sorted, sl. silty, a., good porosity where no authigenic overgrowth occurs, v. friable, sl. micromicaceous, o.s.
0'1"	S.s., as above, but more indurated and regular laminae or v. thin beds of black heavy oil.
4'0"	S.s., mod. brown, qtz., f. to v. f. gr., v. well sorted, A., v. good porosity, v. friable, highly heavy o.s.

Hudson's Bay et al. Bellshill Lake 13-16-41-12W4 (KB 2347)

Core #1: 3012-3047 (rec. 33 ft.)

Thickness	Description
0'5 1/2"	Sh., greyish black, micaceous black, micaceous, silty, silky nodules of pyrite common, firm.
6'0"	Sh., med. grey, sl. micaceous, silty, dull, nodules of pyrite common, hard, brown fossil wood remains intlam. at base with lenticular Sltst., lt. grey, qtz., poor porosity, micaceous, black carbonaceous material scat. throughout.
3'10"	Sltst., lt. grey to yellowish grey, qtz., sl. calc., fairly well indurated, micaceous, black carbonaceous material scat. throughout, brown fossil wood remains (up to several inches long) intlam. with Sh., med. dk. grey, micaceous silty, glossy.

Thickness	Description
17'11"	Sh., dk. grey, micaceous, silty, dull, hard, intlam. or thinly intbd. with Sltst., yellowish grey, qtz., v. poor porosity, well indurated, black carbonaceous material scat. throughout; five seams of S.s., dusky yellow, qtz., v. f. gr., silty, poorly sorted, fair porosity, micaceous, sl. o. s. are also intbd. at: 3'10" from the top of the interval (2" thick) 11'7" " " " " " " (21/4" ") 15'9" " " " " " " (5" ") 16'4" " " " " " " (11/2" ") 18'4" " " " " " " (4" ")
2'4"	S.s., dk. yellowish brown, qtz., v. f. gr. to f. gr., v. sl. silty, fairly well sorted, a., v. good porosity, v. friable, highly o.s.
0'5 1/4"	Sltst., pale yellowish brown, qtz., poor porosity, well indurated, micaceous, black carbonaceous material scat. throughout, thinly intbd. with Sh., greyish black, micaceous, silty, glossy, abundance of black carbonaceous material, hard.
2'0"	S.s., dk. yellowish brown, qtz., v. f. gr., v. well sorted, r., v. good porosity, v. friable, v. highly o. s.

Core #2: 3054 (rec. 6.2 ft.)

Thickness	Description
0'2"	S.s., pale yellowish brown, qtz., f. gr., v. well sorted, a., good to v. good porosity, sl. arg., fairly well indurated, v. sl. pyritic, almost no o. s.
0'7"	S.s., mod. brown; qtz., v. f. gr. to f. gr., v. well sorted, r., v. good porosity, friable, highly o. s.
0'5"	S.s., pale yellowish brown, as above, micaceous.
2'10"	S.s., mod. brown to dusky brown, as above, heavy oil saturation.

Core #3: 3054-3063 (rec. 7 ft.)

Thickness	Description
3'4"	S.s., dk. yellowish brown to mod. brown, qta., v. f. gr., v. well sorted, r., v. good porosity, v. friable, highly o. s.

Thickness	Description
3'8"	S.s., pale yellowish brown to dk. yellowish brown, v. f. gr., qtz., v. sl. silty, well sorted, r., good porosity, v. calc. at top, no calc. at base, well indurated when calc., almost no o. s.

Permo Catalina Bellshill 7-19-41-12W4 (KB 2319)

Core #1: 3020-3033 (rec. 12.8 ft.)

Thickness	Description
0'1"	Sltst., dusky yellow, qtz., v. arg., sl. calc., friable, black carbonaceous material common.
4'2"	Sh., dk. grey with sl. greyish red case, silty, sl. micaceous, dull, nodules of pyrite (up to 1/2") common, black carbonaceous material. Plant remains.
1'9 1/2"	S.s., mod. yellowish brown, qtz., v. f. gr., v. silty, poorly sorted, a., poor to fair porosity, well indurated, carbonaceous material scat. throughout, v. sl. glauconitic, thinly intbd. with v. rare lenticular black Sh.
0'3"	Sh., black micromicaceous, silky, smooth broken surface, sl. loose, thinly intbd. with rare lenticular Sltst., lt. grey, qtz.
0'1/2"	S.s.,mod. yellowish brown, as above, showing sedimentary figures at base.
0'2 1/4"	Sh., black as above.
0'1"	S.s., mod. yellowish brown, as above, thin black shale beds are v. undulating.
0'8 3/4"	S.s., mod. yellowish brown, qtz., v. f. gr., v. silty, a., poor sorting, v. poor porosity, calc., v. arg. in part, where it takes a dk. grey color, fairly well indurated, sl. pyritic.
0'1"	Sh., black as above.
0'1"	S.s., mod. yellowish brown, as above.
3'3"	Sh., greyish black, sl. micaceous, silty, v. friable, intbd. with Coal.
1'10"	S.s., lt. grey, qtz. with authigenic overgrowth, v.f. gr. to Sltst., a., v. poor porosity, arg., fairly hard, dk. carbonaceous material common.

Thickness	Description
0'1"	Sh., black, carbonaceous and coaly material v. common, glossy, sl. pyritic, loose.
0'1/2"	Sh., med. dk. grey, sl. micromicaceous, silty, dull, pyritic nodules common, thinly intbd. with v. irregular bodies of Sltst., lt. grey, qtz., arg., well indurated.

Core #2: 3033-3058 (rec. 25 ft.)

Thickness	Description
0'9"	Sltst., med. grey, qtz. with considerable authigenic overgrowth, v. poor porosity, hard, sl. micaceous, carbonaceous material scat. throughout, base of bed shows undetermined sedimentary figures.
0'1"	Sh., black, sl. micaceous, silty, some coaly flecks and streaks, glossy, fairly well indurated, thinly intbd. with rare, lenticular lt. grey Sltst.
1'5"	Sltst., lt. grey, qtz., arg., v. calc., hard, sl. micaceous, sideritic, black carbonaceous material scat. throughout.
1'9"	Sh., black, thinly intbd. with Sltst., lt. grey as above.
10'6"	Sh., greenish grey to brownish grey, sl. micaceous, v. silty, sparse dk. carbonaceous material, dull, sl. pyritic, rare fossil remains (Ostracods?), minor slickensiding.
5'0"	Sltst.,lt. grey, qtz., with authigenic overgrowth, poor to fair porosity, arg., firm, micaceous, sl. pyritic, black carbonaceous material scat. throughout, brown fossil wood remains (up to several inches long).
3'6"	Sh., dk. grey, micaceous silty, glossy, pyritic, hard, thinly intbd. with lenticular and v. irregular bodies of Sltst., lt. grey calc., as above.
2'0"	S.s., med. bluish grey, qtz., v. f. gr., a., poor to fair porosity, sl.pyritic, v. calc., very hard.

Banff et al. Bellshill Lake 6-21-41-12W4 (KB 2337)

Core #1: 3003-3034 (rec. 27.8 ft.)

Thickness	Description
0'8"	Sh., black sl. silty, dull, coaly material common, pyrite especially at top, well indurated.

Thickness	Description
2'8 1/2"	Sh., greenish grey with sl. greyish red cast, micaceous, silty (silt becoming more prominent toward base), dull, coaly streaks, pyrite abnt., hard.
0'7"	Sh., greyish black, glossy, pyritic, fairly well indurated, thinly intbd. or intlam. (mainly lenticularly) with Sltst., lt. grey, qtz., v. f. gr., v. poor porosity, firm, some worm tracks.
1'2 1/2"	Sh., greenish grey with sl. greyish red cast, sl. micaceous, silty, dull nodules of pyrite abnt., hard.
0'7 3/4"	Sh., as above, fossil remains (?) thinly intlam. with rare lenticular Sltst., lt. grey, qtz.
4'8 1/2"	Sltst., yellowish grey, qtz. with authigenic overgrowth, a., poor porosity, firm, micaceous nodules of pyrite and coal common.
7'4"	Sltst., yellowish grey, qtz., a., poor to fair porosity, firm, micaceous, rare nodules of pyrite, thinly intbd. with Sh., dk. grey, micaceous, silty, glossy, some worm tracks and borings, hard.
2'0"	S.s., pale yellowish brown, qtz. with authigenic overgrowth in part, v. f. gr., fairly well sorted, a., good porosity, firm, micaceous, brown fossil wood remains, sl. o. s., intlam. or thinly intbd. with black Sh.
0'6 1/4"	S.s., mod. yellowish brown, qtz., v. f. gr., well sorted, v. good porosity, firm, highly o.s.
1'5 1/2"	Sh., dk. grey, micaceous, silty, glossy, micropyritic, fairly well indurated, intlam. or thinly intbd. with S.s., yellowish grey, qtz., f. gr., v. silty, poorly sorted, A., fair porosity, firm, micaceous, sl. o. s.
0'10"	S.s., mod. brown, qtz., med. to f. gr., a., v. well sorted, v. good porosity, friable, highly o. s.
0'1"	Sh., dk. grey, micaceous, silty, glossy, carbonaceous material scat. throughout, well indurated.
3'0"	S.s., as above.
0'5"	Sh., dk. grey, micaceous, silty, fairly hard, thinly intbd. or intalm. with Sltst., lt. grey, qtz., A., firm.

Thickness	Description
1'6"	S.s., as above.

Hudson's Bay et al. Bellshill Lake 10-21-41-12W4 (KB 2343.1)

Core #1: 3018-3063 (rec. 41.9 ft.)

Thickness	Description
1'1"	Sh., dk. grey, micaceous, silty, glossy, well indurated, intlam. or v. thinly intbd. with lenticular S.s., lt. grey, qtz., v. f. gr. to Sltst., a., poor porosity, arg., firm micaceous black carbonaceous material scat. throughout.
7'6"	Sltst., yellowish grey, qtz., poor porosity, v. arg., loose, micaceous, sl. o. s., black carbonaceous material scat. throughout, intbd. with S.s., mod. yellowish brown to yellowish grey, depending upon o. s., qtz., silty, A., good porosity, friable, micaceous, o. s. becomes prominent toward the base.
6'4"	S.s., mod. yellowish brown, qtz., v. f. gr., a., v. well sorted v. good porosity, friable, highly o. s.
9'2"	S.s., yellowish grey to mod. yellowish brown, qtz., v. f. gr. v. silty, A., poor to fair porosity, arg., sl. loose, micaceous, sl. o. s. , v. thinly intbd. in part with Sh., med. dk. grey, micaceous, silty, glossy, well indurated, and with S.s., highly o. s., as above.
4'3"	S.s., dk. yellowish brown, qtz., v. f. gr. to f. gr., v. well sorted, r., v. good porosity, v. friable, v. highly o. s.
0'2"	S.s., dk. yellowish rhwon, qtz., v. f. gr. to f. gr., well sorted, a., good to v. good porosity, v. friable, highly o. s.
0'5"	Sh., dk. grey, micaceous, silty, presence of black carbonaceous material, dull, firm, intlam. or thinly intbd. with S.s., greyish orange, qtz., v. f. gr., silty, well sorted, a., good porosity, well indurated, micaceous.
6'1"	S.s., yellowish grey, qtz., sl. silty, well sorted, r. good to v. good porosity, sl. calc., sl. friable.
3'10"	S.s., mod. brown, qtz., v. f. gr., fairly well sorted, a., v. good porosity, v. friable, v. highly o. s.

Richfield Oil Corporation Bellshill Lake 13-22-41-12W4 (KB 2329)

Core #2: 2988-2993 (rec. 5 ft.)

Thickness	Description
0'4"	Sh., black or brownish grey, silty, dull, coaly material common, hard, fossil remains (Ostracods).
1'8"	Sltst., yellowish grey, qtz., calc., v. arg., sl. friable, sl. pyritic, black carbonaceous material scat. throughout.
2'8 1/2"	Sltst., pale yellowish brown, qtz. with authigenic overgrowth, poor porosity, sl. calc., arg., hard, black carbonaceous material scat. throughout.
0'3 1/2"	Coal.

Core #3: 3004-3029 (rec. 25 ft.)

Thickness	Description
7'6"	Sltst., lt. grey, qtz. with authigenic overgrowth, sl. friable, micaceous, sl. o. s., intbd. with S.s., mod. yellowish brown, v. f. gr., v. silty poorly sorted, a., good porosity, fairly well indurated, o. s. scat. throughout, some rare thin seams of Sh., med. dk. grey, micaceous, silty, glossy, firm.
0'3 1/4"	S.s., mod. yellowish brown, qtz., v. f. gr. to silt, fairly well sorted, a., good porosity, well indurated, sl. micaceous, highly o. s.
1'4"	S.s., yellowish grey, qtz., v. f. gr., v. silty, arg., hard, micaceous, black carbonaceous material scat. throughout, intlam. with Sh., dk. grey, micaceous, silty, dull, abundance of carbonaceous material, sl. friable.
0'4 1/4"	Sh., dk. grey, micaceous, dull, micromicaceous, sparse black carbonaceous material, hard, intlam. with rare lt. grey Sltst.
0'4"	S.s., mod. yellowish brown, qtz., v. f. gr. to silt, fiarly well sorted, a., good porosity, sl. friable, sl. micaceous, highly o. s.
5'3"	Sh., Greyish black, micaceous, silty, black carbonaceous material scat. throughout, dull, worm borings common, hard, intbd. with S.s., mod.yellowish brown, qtz., v. f. gr. to silt, fairly well sorted, a., good porosity, sl. friable, sl. micaceous, sl. o. s., sh. beds are thicker than s.s. beds.

Thickness	Description
4'10"	Sh., dk. grey, micaceous, silty, dull, hard, intbd. with Sltst., yellowish grey, qtz., v. c. gr., A., fair porosity, fairly friable, micaceous, black carbonaceous material common, sl. o. s.
1'8"	Sltst., lt. grey, qtz., v. c. gr., a., fair porosity, well indurated, micaceous, with some rare black sh. seams, thinly intbd. with S.s., mod. yellowish brown to dk. yellowish brown, qtz., v. f. gr. to silt, well sorted, A., good to v. good porosity, loose, sl. micaceous, o. s.
0'1"	Sh., dk. grey, micaceous, silty, glossy, black carbonaceous material common, firm, thinly intbd. or intlam. with lenticular Sltst., yellowish grey, v. c. gr., poor sorting, poor porosity, well indurated, micaceous.
1'7"	S.s., mod. yellowish brown to yellowish grey according to o. s., qtz., v. f. gr., sl. silty, a., v. well sorted, good to v. good porosity, friable, highly o. s. in the top foot of the int., v. sl. o. s. at base.
1'10"	Sh., dk. grey, micaceous, silty, dull, fairly well indurated, worm borings common, thinly intbd. with S.s., pale yellowish brown, qtz., v. f. gr., silty, fairly well sorted, fair to good porosity, sl. friable, sl. micaceous, o. s. scat. throughout.

Joe Phillips Bellshill Lake 2-27-41-12W4 (KB2303)

Core #1: 2970-3012 (rec. 42 ft.)

Thickness	Description
3'9"	Sh., greyish black, micaceous, silty, dull pyritic, abnt. carbonaceous material, friable, intlam. or intbd. (beds up to 1") with Coal.
17'9"	Sh., med. grey to dk. grey, micromicaceous at top, sl. silty, abundance of carbonaceous material, dull, pyrite common especially in big nodules (up to several inches) hard, intlam. or thinly intbd. (beds up to 0.5 cm thick) with lenticular Coal.
2'10"	Ls., greenish grey to dk. grey, cryptocrystalline, highly recrystallised, no intercrystalline porosity, no vuggy or fracture porosity, pyrite scat. throughout, siderite in part, v. hard.

Thickness	Description
9'4"	Sh., med. bluish grey to med. dk. grey, sl. silty, dull, abundance of pyrite either highly dissiminated in the rock or in nodules, coaly material common, hard.
8'4"	Sh., med. bluish grey, silty, sl. calc., dull pyrite common, sideritic, carbonaceous material common, hard, intlam. or thinly intbd. (mainly lenticularly) with Sltst., v. lt. grey, qtz., c. gr., poor porosity, arg., calc., well indurated, sl. pyritic, sideritic, sltst. is v. rare at top but becomes abnt. at base. At 1'5" from the base a 2" thick seam is made up of sh. intbd. with S.s., mod. yellowish brown, qtz., f. gr. to v. f. gr., a., well sorted, fair porosity, calc., firm, sl. o. s.

Richfield Oil Corporation Bellshill Lake 3-28-41-12W4 (KB 2309)

Core #1: 2974-3009 (rec. 32.2 ft.)

Thickness	Description
3'7"	Sh., lt. grey, silty, silky, pyritic, black flecks of carbonaceous material v. common in part, sl. loose.
5'1"	Sltst., greenish grey, qtz., a., poor to fair porosity, sl. friable, micaceous, black carbonaceous material scat. throughout, intlam. with rare dk. grey Sh.; sltst. becomes coarser and coarser toward the base.
10'9"	Sltst., greenish grey, qtz., v. c. gr., v. silty, v. poorly sorted, poor to fair porosity, loose micaceous, black carbonaceous material scat. throughout, intbd. with S.s., mod. yellowish brown, qtz., v. f. gr. to silt, well sorted, r., good porosity, friable, highly o. s.; s.s. seams are about 5" thick at top but become thicker toward the base; some rare black Sh. partings are also intlam.
0'5"	Sh., med. dk. grey, micaceous, silty, calc., dull, hard.
12'4"	S.s., yellowish grey or mod. brown, depending on o. s., qtz., v. f. gr., v. silty in part, fairly well sorted, r., good to v. good porosity (poor to fair when silty), friable, micaceous when silty, highly o. s. when silt is absent, silty seams are almost no o. s., they become less prominent toward the base, some rare black Sh. partings are intlam.

Richfield McLennan F 4-32-41-12W4 (KB 2285)

Core #1: 3056-3074 (rec. 9.6 ft.)

Thickness	Description
2'10"	Cement
0'7"	Sltst., greyish orange, qtz., v. c. gr., poor to fair porosity, arg. in part, well indurated, sl. micaceous, intlam. with Sh., dk. grey, micaceous, silty, dull, coaly material v. common in part, some xbdg.
6'1"	S.s., lt. olive grey, qtz., f. gr. to v. f. gr., well sorted, a., fair to good porosity, arg., sl. friable, micaceous, considerable amount of coaly material scat. throughout, giving the rock a dk. color, intlam. at top of the int. with Sh., as above.

Core #2: 3074-3079 (rec. 2.6 ft.)

Thickness	Description
2'6"	S.s., lt. olive, qtz., f. gr. to v. f. gr., well sorted, a., v. good porosity, friable, micaceous, sideritic, abundance of small black grains scat. throughout (coaly material), some rare lenticular dk. Sh. partings are intlam.

Core #3: 3079-3081 (rec. 2 ft.)

Thickness	Description
2'0"	S.s., as above, but no sh. partings intlam.

Cores #4 and 5: 3083-3096 (rec. 3.6 ft.)

Thickness	Description
0'4"	Sh., med. dk. grey, micaceous, silty, glossy, carbonaceous material v. common, sl. loose, showing a dip of about 40°.
0'7"	S.s., yellowish grey, as above, but almost no black coaly particles and thus the rock color is lighter.
0'1"	Sh., as above, also showing a 40° dip.
0'7"	S.s., as above, but no coaly particles
2'1"	S.s., as above, presence of some c. to v. c. grains and silt decreasing the porosity.

Core #6: 3096-3113 (rec. 14 ft.)

Thickness	Description
9'0"	S.s., yellowish grey, qtz., f. gr. but also some rare v. c. angular grains, well to v. well sorted, a., or r., v. good porosity, v. friable, micaceous, presence of one seam (1" thick) of Sh., med. dk. grey, micaceous, silty, dull, well indurated.
3'7"	S.s., as above but presence of silt decreasing sl. the porosity, intbd. (beds up to 2-3" thick) with Sh., med. bluish grey, micaceous, silty, dull.
1'5"	S.s., yellowish grey, qtz., f. gr. but also presence of c. grains, well sorted, r., v. good porosity, friable, micaceous.

Core #7: 3113-3131 (rec. 1.3 ft.)

Thickness	Description
1'3"	S.s., as above, presence of long brown remains of wood.

Core #8: 3131-3144 (rec. 12.5 ft.)

Thickness	Description
2'7"	S.s., yellowish grey, qtz., f. gr., sl. silty in part, r., v. good porosity, friable, micaceous, presence of rounded dk. grey sh. pebbles (up to 1/2" long); at top of the int., a (2" thick) seam of Sh., dk. grey with sl. greenish cast.
9'10"	S.s., yellowish grey to med. grey, qtz., f. gr. but also presence at base of c. size grains, v. well sorted, r., v. good porosity, friable, locally presence of v. small black particles (coaly material ?) giving the rock a darker color.

Core #9: 3144-3146 (rec. 2 ft.)

Thickness	Description
0'6"	S.s., color is banded, dk. yellowish brown or lt. grey depending on o. s., v. f. gr., sl. silty, fairly well sorted, a., fair to good porosity, friable, alternatively not o. s. or highly o. s. depending upon silt content.

Thickness	Description
1'6"	S.s., yellowish grey to dk. yellowish brown, qtz., f. to med. gr., well sorted, a., v. good porosity, sl. friable, some qtz. grains in locally sl. iron stained, o. s. in part, laminae appear at top indicating a 10° dip.

Core #10: 3147-3160 (rec. 5 ft.)

Thickness	Description
0'7"	S.s., as above, but mottled (mod. yellowish brown patches), presence of black nodules of coaly material.
0'7"	S.s., mottled as above but patches are dusky yellowish brown, giving the rock a darker color.
3'10"	Sh., dk. grey, micaceous especially on bedding planes, silty, dull, black carbonaceous material scat. throughout, hard, intlam. or thinly intbd., mainly regularly, with S.s., v. lt. grey, qtz., v. f. gr., v. silty, a., poor porosity, well indurated, xbdg. in part at base.

Richfield McLennan F 10-32-41-12W4 (KB 2295)

Core #1: 2959-3989 (rec. 26 ft.)

Thickness	Description
1'3"	S.s., lt. grey, qtz. with authigenic overgrowth in part, v. f. gr., silty, poorly sorted, a., poor to fair porosity in part, well indurated, v. sl. glauconitic, micromicaceous, considerable amount of carbonaceous material highly disseminated or in nodules up to 1/2" diameter, brown colored wood fossil remains up to several inches long common.
3'4"	S.s., to Sltst., as above, mottled lt. grey to yellowish grey, also abundance of carbonaceous material, loose.
2'11"	Sh., from lt. grey to med. dk. grey, micaceous, v. silty, dull, carbonaceous material common, pyritic, hard, intlam. with Sltst., v. lt. grey, micro-micaceous, carbonaceous material disseminated, sparse worm borings filled with sltst.
1'0"	S.s., pale olive, qtz., f. gr., silty, arg., a., poor to fair porosity, v. sl. calc., well indurated, f. pyritic, carbonaceous material scat. throughout common.

Thickness	Description
0'5"	Sh., black, sl. silty, glossy, pyritic, hard, coaly flecks and streaks, with rare irregular laminae of Sltst., lt. grey.
4'1"	Sh., med. grey, dull, pyritic either in small nodules or in thin rods (up to 1" long), carbonaceous material scat. throughout, hard.
1'6"	S.s., lt. olive grey, qtz. with considerable authigenic overgrowth, v. f. gr., silty, arg., a., poor porosity, well indurated, abnt. carbonaceous material scat. throughout, heavy o.s.
2'11"	Sh., black, with abnt. coaly flecks and streaks, glossy, smooth broken surface, hard, intbd. with Coal.
1'4"	Sltst., yellowish grey, c. gr., qtz., arg., hard, pyritic, carbonaceous material common.
1'1"	Sh., black, intbd. with Coal, as above.
1'1"	Sltst.,lt. grey, qtz., med. c., arg., sl. calc., well indurated, sparse small nodules or pyrite, with coaly flecks and streaks, intbd. especially at base of the int. with black Sh. whose thickness of beds does not exceed 2-3 mm.
3'6"	Sh., dk. grey to black, usually sl. silty but the content in silt may increase considerably in part making appear thin lensoid, lt. grey seams, glossy, smooth broken surface, small elongated pyritic patches on bedding planes, intbd. at top of the int. with thin beds of Coal.
1'7"	Sh., lt. bluish grey, silty, dull pyrite common, sl. indurated.

Core #2: 2989-2999 (rec. 9.8 ft.)

Thickness	Description
8'5"	Sh., lt. grey becoming darker at base, silty, dull scat. carbonaceous material, pyrite common either in nodules or in thin seams, micaceous, well indurated, minor slickensiding at base.
1'3"	Sh., dk. grey, micaceous, silty, dull rough broken surface, sl. pyritic, sparse carbonaceous material, hard, intbd. or mainly irregularly intlam. with S.s., v. f. gr. to Sltst., greyish orange, qtz.,

Thickness	Description
	arg., fairly well indurated, scat. o.s. throughout, sbdg. appears in part.

Core #3: 2999-3009 (rec. 10 ft.)

Thickness	Description
10'0"	Sh., dk. grey, intlam. with S.s. to Sltst., greyish orange, as above, thick s.s. seams are also intbd. at: 1' 2" (thickness 6") 3'10" (" 4") 6' 9" (" 8") 7'10" (" 1'3")

Core #4: 3009-3019 (rec. 8.8 ft.)

Thickness	Description
8'8"	S.s. to Sltst., as above, intlam. with Sh., as above; thick oil saturated S.s., as above, are also intbd. at: 1' 1" (thickness 6") 1'10" (" 7") 2'11" (" 10") 4' 9" (" 3") 5' 2" (" 8") from the top of the int.

Hudson's Bay et al. Bellshill Lake 1-33-41-12W4 (KB 2283)

Core #1: 2973-3011 (rec. 35 ft.)

Thickness	Description
0'9"	S.s., v. f. gr., to Sltst., yellowish grey, qtz., a., firm, micaceous, sl. o. s., intlam. or thinly intbd. (mainly irregularly) with Sh., greyish black, micaceous, silty, abnt. bituminous material, sl. loose.
0'3"	S.s., mod. yellowish brown, qtz.with authigenic overgrowth in part, v. f. gr., silty, a., fairly well sorted, good porosity, sl. loose, o. s. scat. throughout.
0'9 1/2"	Sltst., lt. grey, qtz., a., well indurated sl. calc., sl. pyritic, sl. sideritic, micaceous, sl. o. s., abundance of carbonaceous and bituminous material making thin regular dk. laminae.
0'2 1/2"	S.s., mod. yellowish brown, qtz., with authigenic overgrowth, v. f. gr., silty, a., poorly sorted, firm, micaceous, highly o. s., intlam. (mainly

Thickness	Description
	irregularly) with Sh., greyish black, micaceous, silty, oily, friable, abundance of carbonaceous and bituminous material.
12'4"	Sh., greyish black to med. grey, micaceous, silty, carbonaceous material in part, dull, fairly well indurated, thinly intbd. or intlam., mainly lenticularly with S.s., v. f. gr. to Sltst., lt. grey to greyish orange, qtz., a., fair porosity, firm, micaceous, sl. o. s. Bed thickness variable from the thickness of a laminae up to 1"; at 1'10" from the base of the int., shale makes up irregular bodies throughout the s.s.
1'8"	S.s., mod. yellowish brown, qtz., v. f. gr., a. well sorted, good porosity, sl. friable, o.s. scat. throughout, xbdg. in part, some irregular bodies of black sh. are scat. throughout the s.s., at 5" from the top of the int. a 3/4" black seam of Sh., med. grey, micaceous, silty, carbonaceous material common, dull, sl. loose.
1'0"	Sh., med. grey, micaceous, silty, carbonaceous material common, dull, fairly well indurated, intlam. or thinly intbd., mainly irregularly with S.s., mod. yellowish brown, qtz., f. gr., silty, fairly well sorted, A., good porosity, sl. loose, sl. o. s., xbdg.
2'7"	S.s., mod. yellowish brown, qtz., v. f. gr., a., well sorted, good porosity, sl. friable, micaceous, highly o. s.
0'9"	Missing (removed for Bacteria Studies)
1'8"	S.s., greyish orange to mod. yellowish brown, qtz., v. f. gr., silty, poor sorting, A., fair porosity, fairly well indurated, micaceous, sl. o. s., intbd. with v. irregular bodies of Sh., med. dk. grey, micaceous, silty, dull pyrite common, well indurated, s.s. becomes more prominent and more highly o.s. at base.
0'4"	Missing
0'3 1/2"	S.s., dk. yellowish brown, qtz. with authigenic overgrowth in part, v. f. gr., silty, fairly well sorted, a., fair porosity, fairly well indurated, highly o. s.

Thickness	Description
4'5"	S.s., yellowish grey, qtz., v. f. gr., silty, well sorted, a., fair porosity, well indurated, v. sl. o. s.; s.s. includes thin beds or pebbles of Sh., dk. grey, micaceous, sl. silty carbonaceous material common, dull, well indurated.
1'9"	S.s., mod. yellowish brown, qtz., f. gr., well sorted, a., v. good porosity, friable, o.s.
6'3"	S.s., yellowish grey, qtz., f. gr., sl. silty, well sorted, a., v. good porosity, sl. friable, sl. micaceous in part, v. sl. o. s. - At 2'3" from the top if the int. a 5" seam where s.s. is thinly intbd. (very irregularly) with Sh., dk. grey, micaceous, silty, dull, sl. pyritic in part, well indurated. At 5'9" from the top of the int., shale makes up very irregular pebbles (on 1" thickness).

Tower Killam No. 1 5-18-42-13W4 (KB 2284)

Core #47: 2963-2969 (rec. 2.3 ft.)

Thickness	Description
2'3"	Sltst., lt. grey, qtz., c. gr., v. poor porosity, sl. calc., arg., well indurated, glauconitic, micaceous, abundance of black carbonaceous material scat. throughout, iron staining (siderite), intlam. with Sh., med. dk. grey, micaceous, silty, with coaly flecks and streaks, shreds of white mica especially on bedding plances; xbdg. in part.

Core #48: 2969-2977 (rec. 9.6 ft.)

Thickness	Description
9'6"	Sltst., lt. grey to dusky yellow, mottled, glauconitic as above, thinly intbd. with Sh., as above; sh. becomes prominent and darker toward the base; xbdg. v. common.

Core #49: 2977-2985 (rec. 8.7 ft.)

Thickness	Description
5'6"	Sltst., lt. grey, mottled in part, glauconitic, as above, thinly intbd. mainly irregularly with Sh., dk. grey, as above, sltst. becomes prominent at base.

Thickness	Description
0'8"	Sltst., lt. grey, glauconitic, as above, some rare "patches" of irregular laminae of dk. grey Sh., as above.
2'5"	Sh., dk. grey, glossy, smooth broken surface, nodules of pyrite (up to 1/2 inch) are common.

Core #50: 2985-2993 (rec. 5.10 ft.)

Thickness	Description
0'5"	Sh., dk. grey, as above.
5'5"	Sh., dk. grey, as above, v. irregularly intlam. with S.s., lt. grey, f. gr., a.

Core #51: 2993-2998 (rec. 3.5 ft.)

Thickness	Description
3'5"	S.s., yellowish grey to dusky yellow, qtz., v. f. gr., very silty in part, well sorted, a., poor to fair porosity, sl. calc., well indurated, v. sl. glauconitic, micaceous, black coaly material, v. common, sl. o. s. in part, a few laminae of dk. sh. appear throughout.

Core #52: 2998-3004 (rec. 4.6 ft.)

Thickness	Description
4'6"	S.s., as above, although pyritic and sideritic, intlam. or v. thinly intbd. with Sh., med. grey, micromicaceous, sl. silty, dull, firm.

Core #53: 3004-3010 (rec. 8.11 ft.)

Thickness	Description
5'2"	Sltst., lt. grey, qtz., v. poor porosity, fairly arg., loose, micaceous, coaly material scat. throughout, thinly intbd. with Sh., as above, abundance of coaly material.
3'9"	Sh., dk. grey, v. sl. sandy, silky, loose, abundance of black carbonaceous material, intlam. or thinly intbd. with Coal.

Core #54: 3010-3016 (rec. 2.4 ft.)

Thickness	Description
2'4"	S.s., yellowish grey, qtz., with authigenic

Thickness	Description
	overgrowth, v. f. gr., silty, a., fairly well sorted, fair porosity, well indurated, black carbonaceous material scat. throughout, brown iron staining.

Core #55: 3016-3024 (rec. 9.4 ft.)

Thickness	Description
2'7"	Sh., black, glossy, smooth broken surface, with coaly streaks, friable.
1'4"	S.s., yellowish grey, as above.
1'0"	Sltst., lt. olive grey, qtz., r., v. poor porosity, calc., hard, micaceous, v. sl. glauconitic.
1'1"	Sh., dk. grey, glossy, smooth broken surface.
0'9"	Sh., dk. grey, micromicaceous, silty, dull, sl. pyritic, abundance of coaly flecks, firm, v. irregularly intbd. with lenticular S.s., lt. grey, qtz. with authigenic overgrowth, v. f. gr., v. silty, almost non porous, well indurated, f. coaly material scat. throughout.
2'7"	Sh., med. dk. grey, micromicaceous, glossy, v. loose.

Core #56: 3024-3027 (rec. 3.8 ft.)

Thickness	Description
1'0"	Ls., yellowish grey, sublithographic, no apparent porosity, some rare black carbonaceous material.
1'0"	Sh., black, silty, dull, relatively smooth broken surface, v. sl. glauconitic, loose.
1'0"	Sh., greenish grey, micromicaceous, v. silty, dull, coaly material flecks in part.
0'8"	Ls., yellowish grey, as above, v. sl. glauconitic.

Core #57: 3027-3035 (rec. 9.1 ft.)

Thickness	Description
3'10"	Ls., yellowish grey, as above.
5'3"	Sh., greenish grey as above, sl. calc., v. friable, pyritic, minor slickensiding in part.

Core #58: 3035-3043 (rec. 5. 11 ft.)

Thickness	Description
5'11"	Sltst., yellowish grey to lt. grey, qtz., arg., calc., well indurated, micaceous, sideritic, pyritic, some rare black carbonaceous material scat. throughout, intlam. or very thinly intbd. with Sh., med. grey, micaceous especially on bedding planes, silty, black, carbonaceous material scat. throughout, hard.

Core #59: 3043-3049 (rec. 6.3 ft.)

Thickness	Description
1'7"	Sltst., thinly lenticularly intbd. with Sh., as above, pyritic.
2'7"	Sh., med. dk. grey, sl. silty, dull sl. pyritic, with coaly flecks and streaks, loose.
2'1"	Sltst., v. lt. grey, qtz., v. arg., sl. friable, micaceous, sl. pyritic, sl. sideritic, black carbonaceous material scat. throughout.

Core #60: 3081-3087 (rec. 6 ft.)

Thickness	Description
6'0"	Sh., greyish black, silty, dull pyritic, firm, thinly intbd. with lenticular Sltst., v. lt. grey to med. grey, qtz., v. poor porosity, calc., (highly calc. at top, calcitic cement), v. well indurated, micaceous, abundance of carbonaceous material scat. throughout the rock, shale becomes prominent at base.

Core #61: 3087-3095 (rec. 5.10 ft.)

Thickness	Description
4'1"	Sh., as above, thinly intbd. with lenticular Sltst., as above, highly calc. (calcite cement), sh. becomes prominent toward the base.
1'9"	Sh., dk. grey to med. bluish grey, micromicaceous, dull, pyritic, abundance of coaly material.

Core #62: 3095-3103 (rec. 4.2 ft.)

Thickness	Description
0'9"	Sh., as above, thinly intbd. with Sltst., mod. greenish yellow, qtz., v. f. gr., sl. friable.

Thickness	Description
3'5"	Sh., med. dk. grey, micaceous, silty, glossy, micropyritic, black carbonaceous material in part, v. hard.

Core #63: 3103-3109 (rec. 6 ft.)

Thickness	Description
0'3"	Sh., med. dk. grey as above.
5'9"	S.s., mod. yellowish brown to dusky brown depending upon o. s., qtz., v. f. gr. to silt, poorly sorted, A., fair to good porosity, well indurated, micaceous, sl. pyritic, highly o. s. in part.

Core #64: 3109-3114 (rec. 5 ft.)

Thickness	Description
5'0"	Sh., dk. grey as above, intbd. (beds up to several inches thick) with S.s., dusky brown, highly o. s. as above.

Core #65: 3114-3122 (rec. 7 ft.)

Thickness	Description
7'0"	Sh., dk. grey as above, intbd. with S.s., dusky brown, highly o. s. as above.

Core #66: 3123-3127 (rec. 4.2 ft.)

Thickness	Description
4'2"	As above, but S.s. is less o. s., presence of worm borings (?).

Core #67: 3127-3135 (rec. 7.8 ft.)

Thickness	Description
7'3"	As above, sb. becoming prominent at base.
0'5"	S.s., yellowish grey, qtz., v. f. gr., sl. silty, A., v. well sorted, v. good porosity, sl. friable, micaceous.

Core #68: 3135-3143 (rec. 8.6 ft.)

Thickness	Description
3'0"	S.s., yellowish grey as above, o. s. in part.

Thickness	Description
2'8"	S.s., as above, although more silty, thinly intbd. with Sh., med. dk. grey, micaceous especially on bedding planes, silty, dull sparse black carbonaceous material, hard.
2'10"	S.s., yellowish grey, pale yellowish brown at top, f. gr., silty, v. well sorted, r., v. good porosity except at top (almost non porous), calc., highly calc. at top, generally friable but hard at top, sl. pyritic, rare black carbonaceous material scat. throughout.

Core #69: 3143-3151 (rec. 5.6 ft.)

Thickness	Description
5'6"	S.s., yellowish grey, as above.

Core #70: 3151-3159 (rec. 2.1 ft.)

Thickness	Description
2'1"	S.s., yellowish grey, as above, some c. grains of qtz.

Core #71: 3159-3167 (rec. 7.6 ft.)

Thickness	Description
1'1"	S.s., yellowish grey, as above.
6'5"	Sh., pale yellowish brown with sl. greenish cast, micaceous especially on bedded planes, v. silty, in part sl. loose, chlorite (?), abundance of black carbonaceous material, v. thinly intbd. with S.s., yellowish grey, qtz., f. gr., silty, well sorted, a., good porosity, friable, sl. o. s. in part, some s.s. seams are up to 10" thick.

Core #72: 3167-3175 (rec. 7.2 ft.)

7'2"	Sh., as above (abundance of chlorite giving a greenish color), thinly intbd. with S.s., as above, sbdg. common.

Core #73: 3175-3184 (rec. 5.8 ft.)

4'3"	Sh., as above, thinly intbd. with S.s., as above.
1'5"	S.s., v. lt. grey, qtz., f. gr., v. silty, poorly sorted, r., poor to good porosity depending upon silt content, well indurated, micaceous, black carbonaceous material scat. throughout, presence of some rare laminae of black sh.

Core #74: 3184-3192 (rec. 7.1 ft.)

Thickness	Description
7'1"	S.s., v. lt. grey, as above including at top rounded pebbles (up to 1") of Sh., med. dk. grey, micaceous, silty, dull, fairly hard, carbonaceous material.

Core #75: 3192-3200 (rec. 5.9 ft.)

Thickness	Description
5'9"	S.s., v. lt. grey, as above, including rounded pebbles of Sh., med. dk. grey as above, pebbles are small at top (3-4 mm) but they are up to 1 inch at base.

Core #76: 3200-3205 (rec. 3.5 ft.)

Thickness	Description
1'10"	S.s., yellowish grey, qtz., v. well sorted, r., v. good porosity, calc., well indurated, micaceous.
1'7"	S.s., lt. bluish grey (qtz.), rounded, f. gr., also presence of rare coarse grains, v. poor porosity, v. calc. includes abnt. r. pebbles of Sltst., greenish grey, qtz., v. arg., well indurated, micaceous, black carbonaceous material scat. throughout.

Abbreviations used in core descriptions

sh.	- shale	gr.	- grain (ed, s)
sltst.	- siltstone	A.	- angular
s.s.	- sandstone	a.	- subangular
ls.	- limestone	r.	- subrounded
arg.	- argillaceous	R.	- rounded
calc.	- calcareous	w.R.	- well rounded
qtz.	- quartz	abnt.	- abundant
intbd.	- interbedded	dk.	- dark
xbd.	- cross-bedded	ft.	- feet
xbdg.	- cross-bedding	int.	- interval
lam.	- laminated	lt.	- light
xlam.	- cross-laminated	mod.	- moderately
v.f.	- very fine	o.s.	- oil stain (ing)
f.	- fine	rec.	- recovery
med.	- medium	scat.	- scattered
c.	- coarse	sl.	- slightly
v.c.	- very coarse		

PLATE 1

Thin Section Photomicrographs

Figure 1 — Ellerslie Member; silica cement occurring as authigenic overgrowth in optical continuity with quartz grains, note a thin film of impurities marks the boundary between the detrital grain and the authigenic overgrowth; also note only a few inclusions in the overgrowth. (5-18-42-13W4, 3201 ft.), crossed nicols, X124.

Figures 2 and 3 — Ellerslie Member; showing calcite cement replacing quartz grains; calcite polarizes in higher order colours when replacing quartz (see edges of grains), (5-18-42-13W4, 3204 ft.), crossed nicols, X124.

Figure 4 — "Calcareous" member; argillaceous limestone with ostracod, also note presence of quartz grains (5-18-42-13W4, 3028 ft.), plane light, X124.

Figure 5 — "Calcareous" member; showing clay "concretion" included in sandstone (10-32-41-12W4, 2972 ft.), plane light, X31.

Figure 6 — "Calcareous" member; showing calcite cement replacing quartz grains and silica cement (7-19-41-12W4, 3052 ft.), crossed nicols, X124.

Figure 7 — "Calcareous" member; contact between two sedimentary units; "laminae" in lower unit are not parallel to the base of the upper unit (coarser grained) (7-19-41-12W4, 3028 ft.), crossed nicols, X31.

Figure 8 — Channel sandstone; matrix composed of clay, iron oxide and quartz, making up a thin bed, note presence of rounded grains and angular grains in coarser part (3-12-41-12W4, 3252 ft.) crossed nicols, X31.

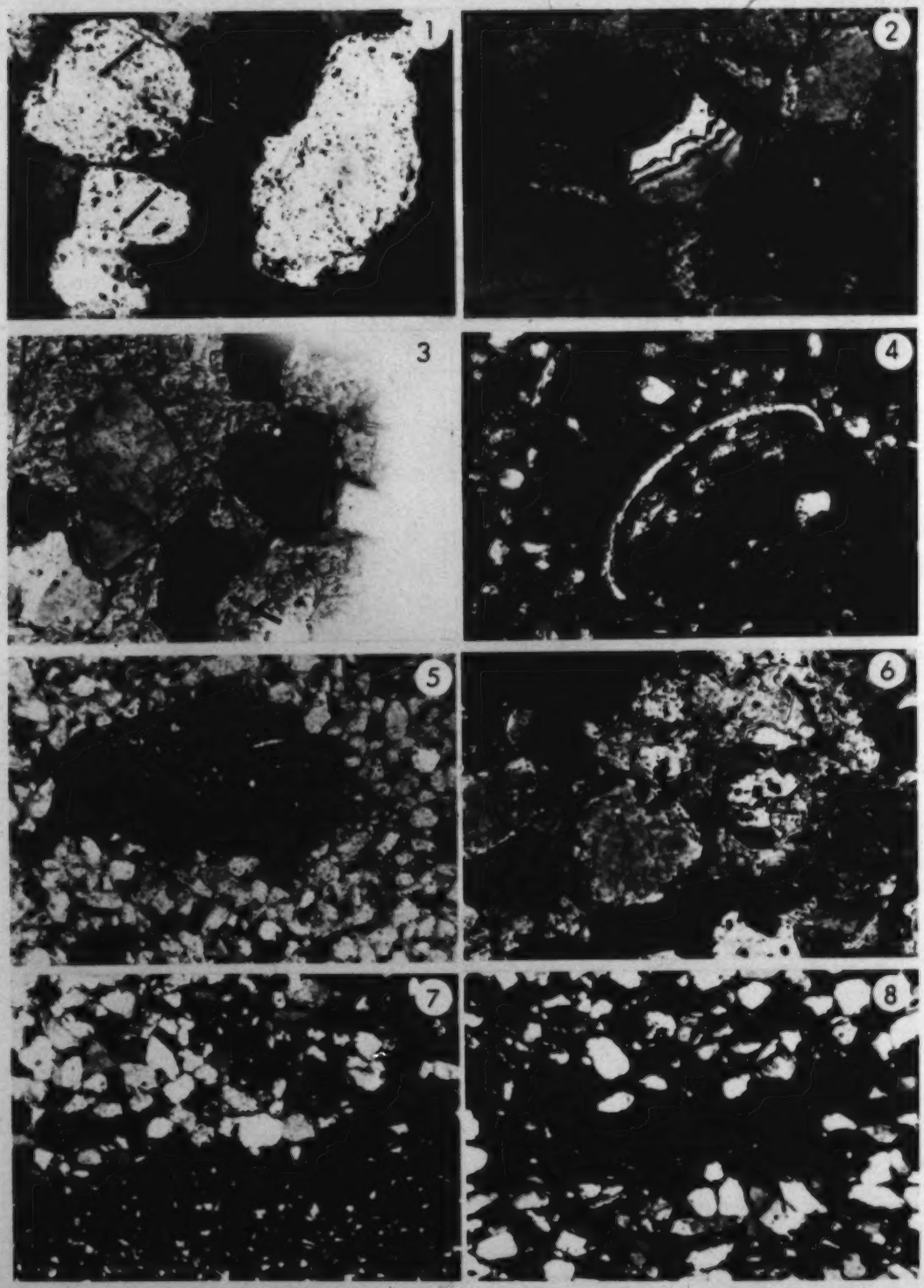
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PLATE II

Thin Section Photomicrographs

Figure 1 — Channel sandstone; showing thin films of matrix (essentially clay) around quartz grains (4-15-41-12W4, 3129 ft.), plane light, X31.

Figure 2 — Channel sandstone; showing calcite cement replacing quartz grains, note "skeleton" of replaced grain in centre of picture (4-15-41-12W4, 3129 ft.), crossed nicols, X124.

Figure 3 — Channel sandstone; showing distribution of grains in laminae, note variation in grain size (8-15-41-12W4, 3140 ft.), crossed nicols, X31.

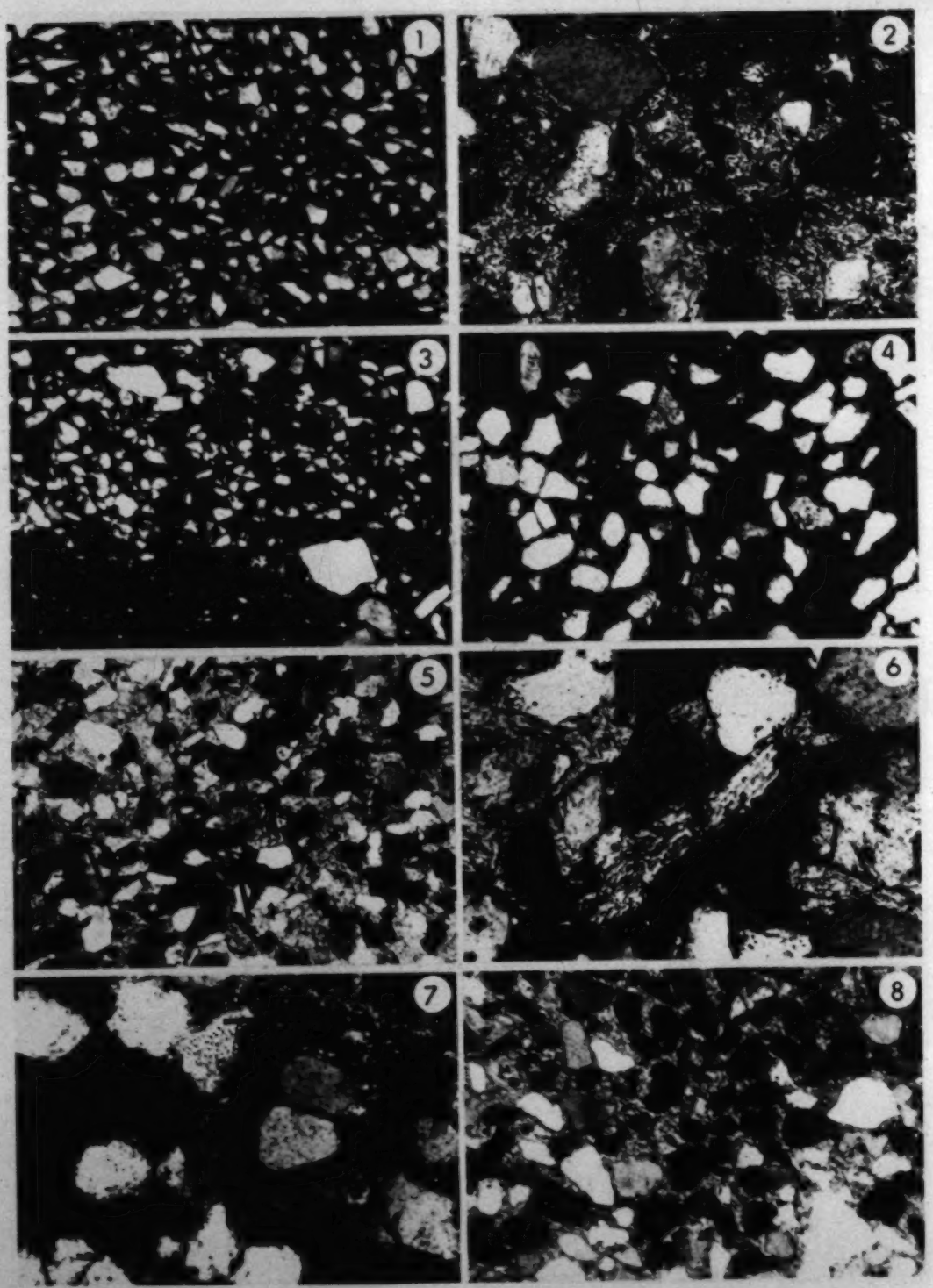
Figure 4 — Channel sandstone; homogeneous thin section representative of most of the samples from channel; grains mostly subangular (13-16-41-12W4, 3055 ft.), crossed nicols, X31.

Figure 5 — Channel sandstone; sandstone cemented by calcite, abundance of chert (13-16-41-12W4, 3059 ft.), crossed nicols, X31.

Figure 6 — Channel sandstone; showing muscovite compressed between quartz grains and taking, because of its plasticity, a fan-like shape in intergranular space (13-16-41-12W4, 3059 ft.), crossed nicols, X124.

Figure 7 — Clearwater Formation; example of secondary cement: calcite cement is filling up spaces between grains; grains are mostly contiguous (4-15-41-12W4, 3050 ft.), crossed nicols, X124.

Figure 8 — Ellerslie Member; example of primary cement, grains "float" in cement (5-18-42-13W4, 3204 ft.), crossed nicols, X31.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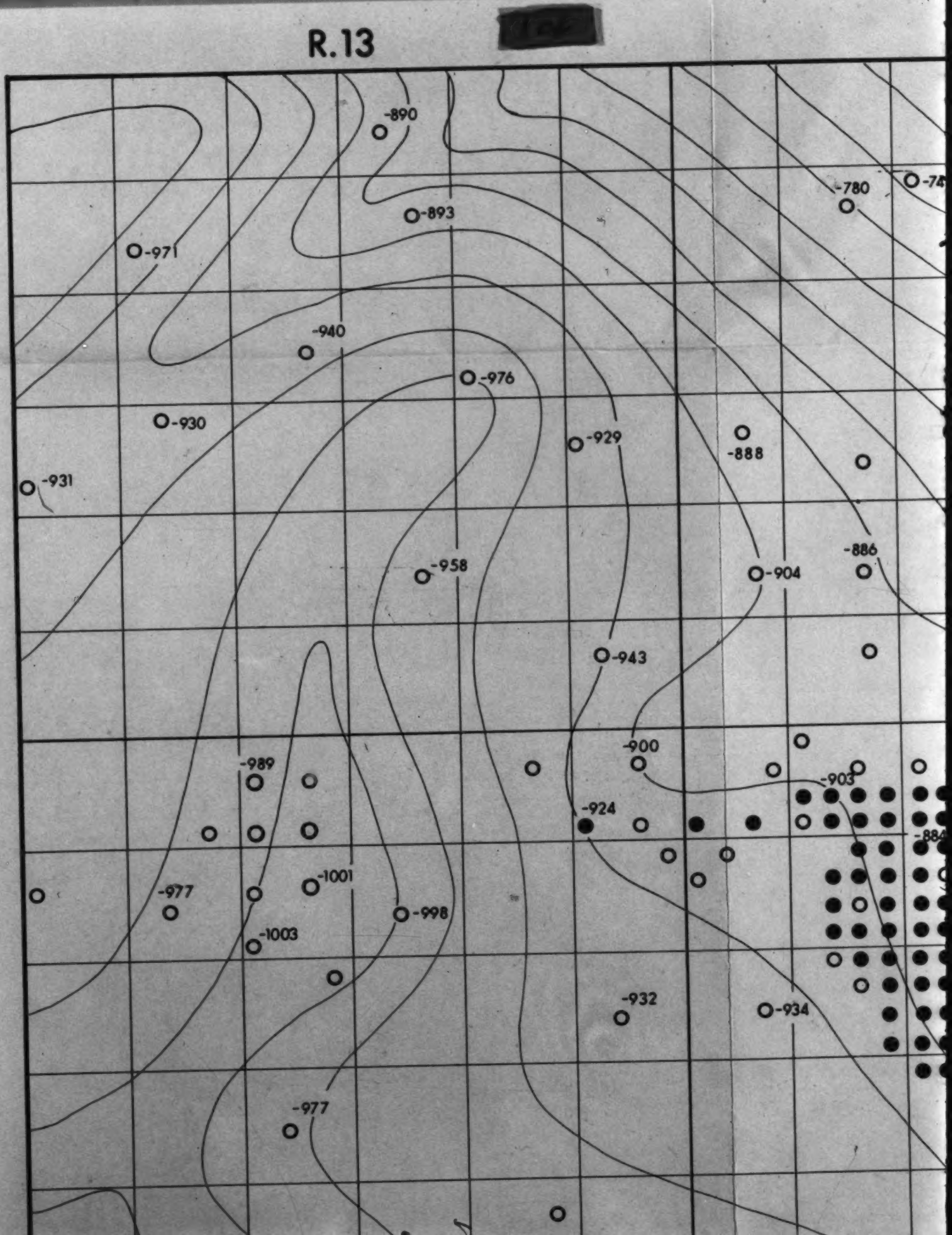
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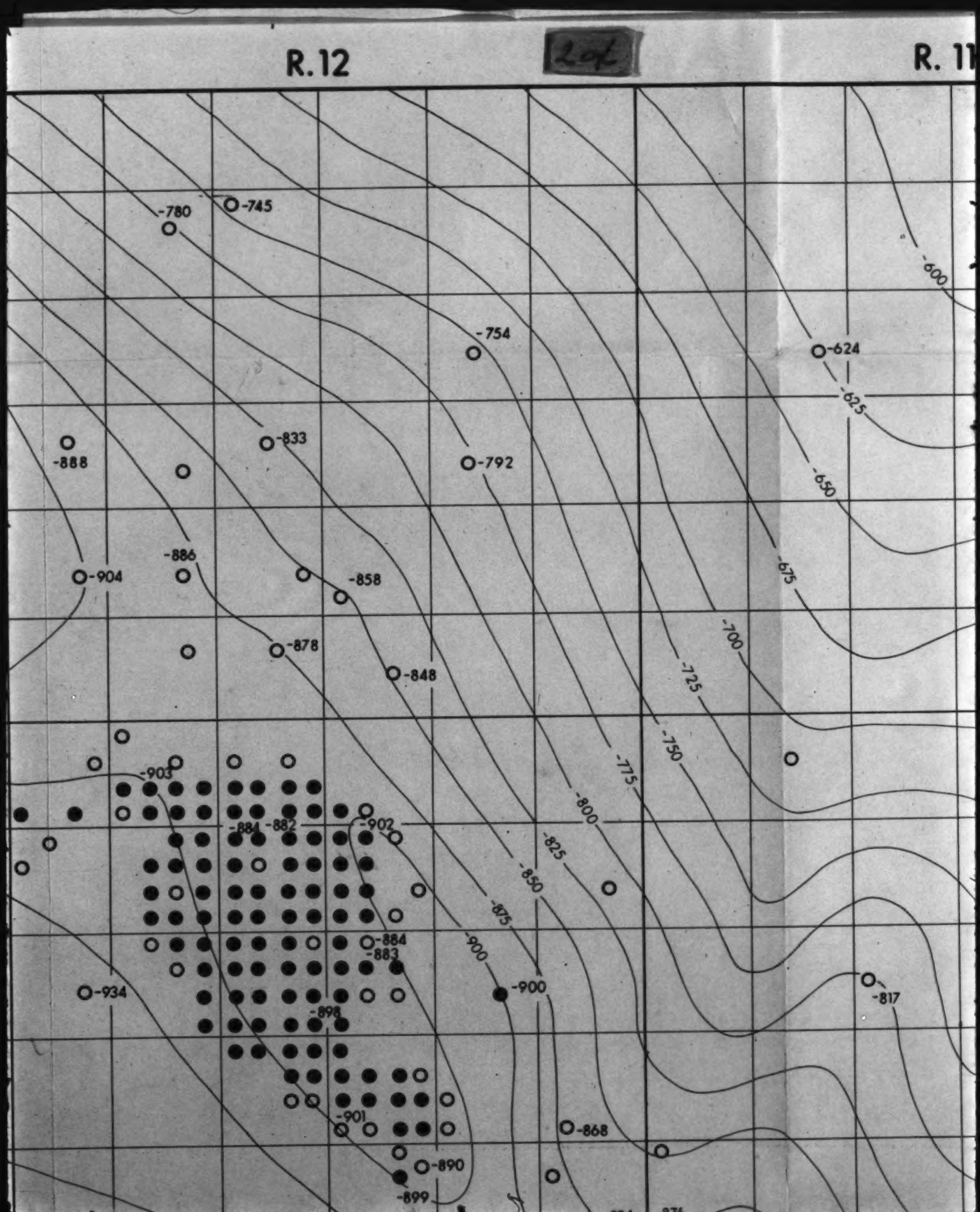
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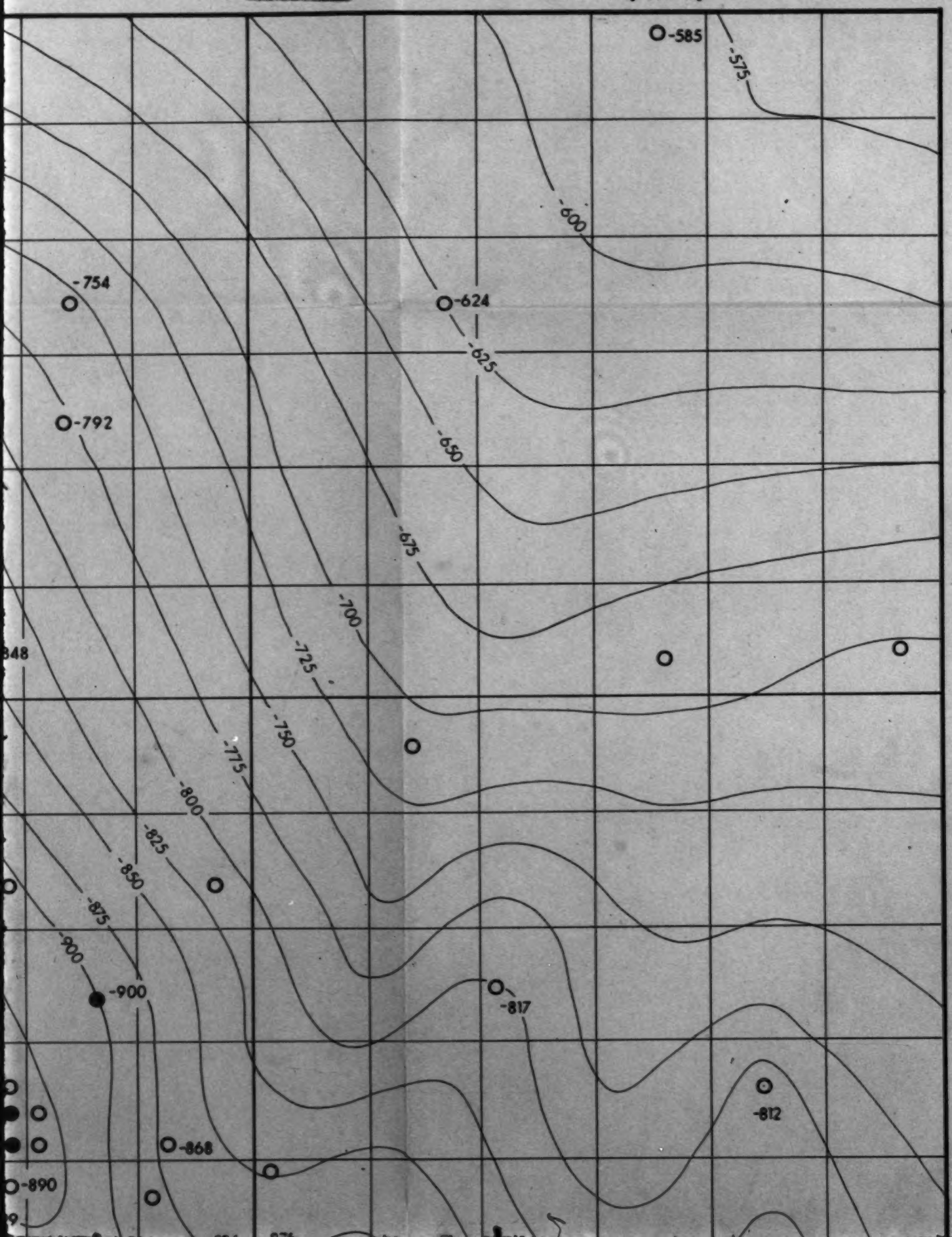
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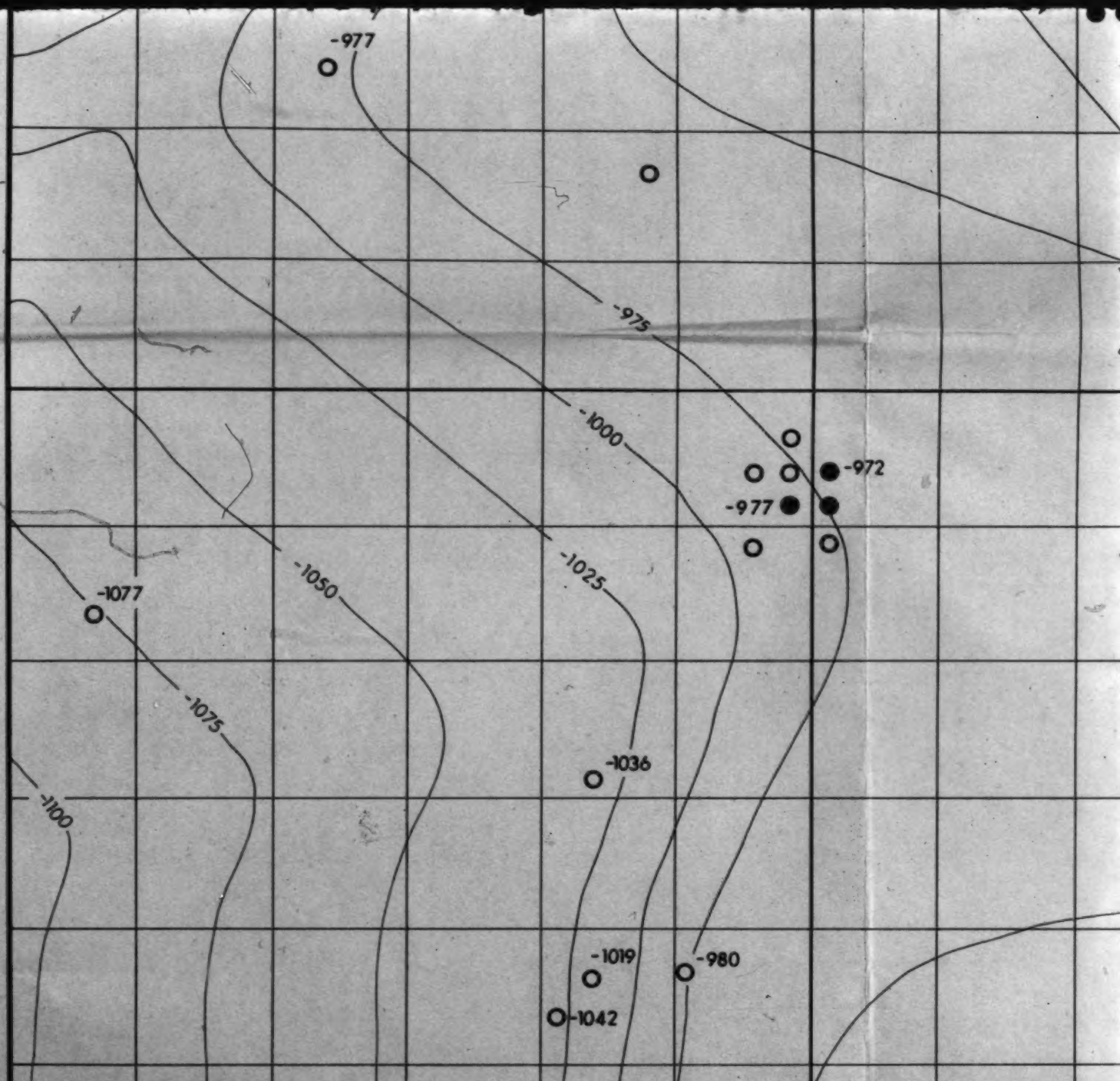
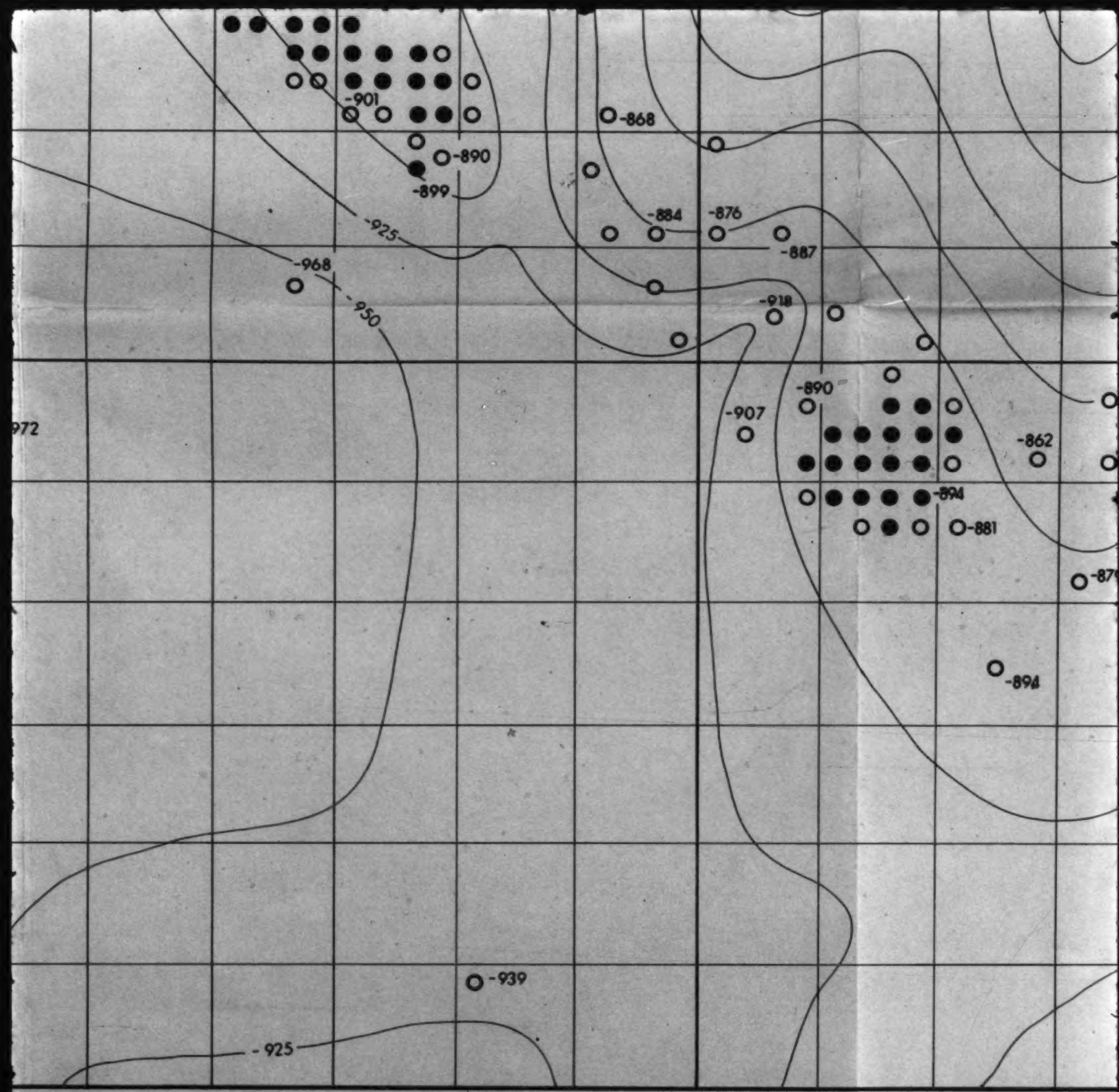


Figure 2. Structure Contour Map Of The Pre-Mannville Surface Bellshill Lake Area, Alberta.



Map Of

Scale in mile

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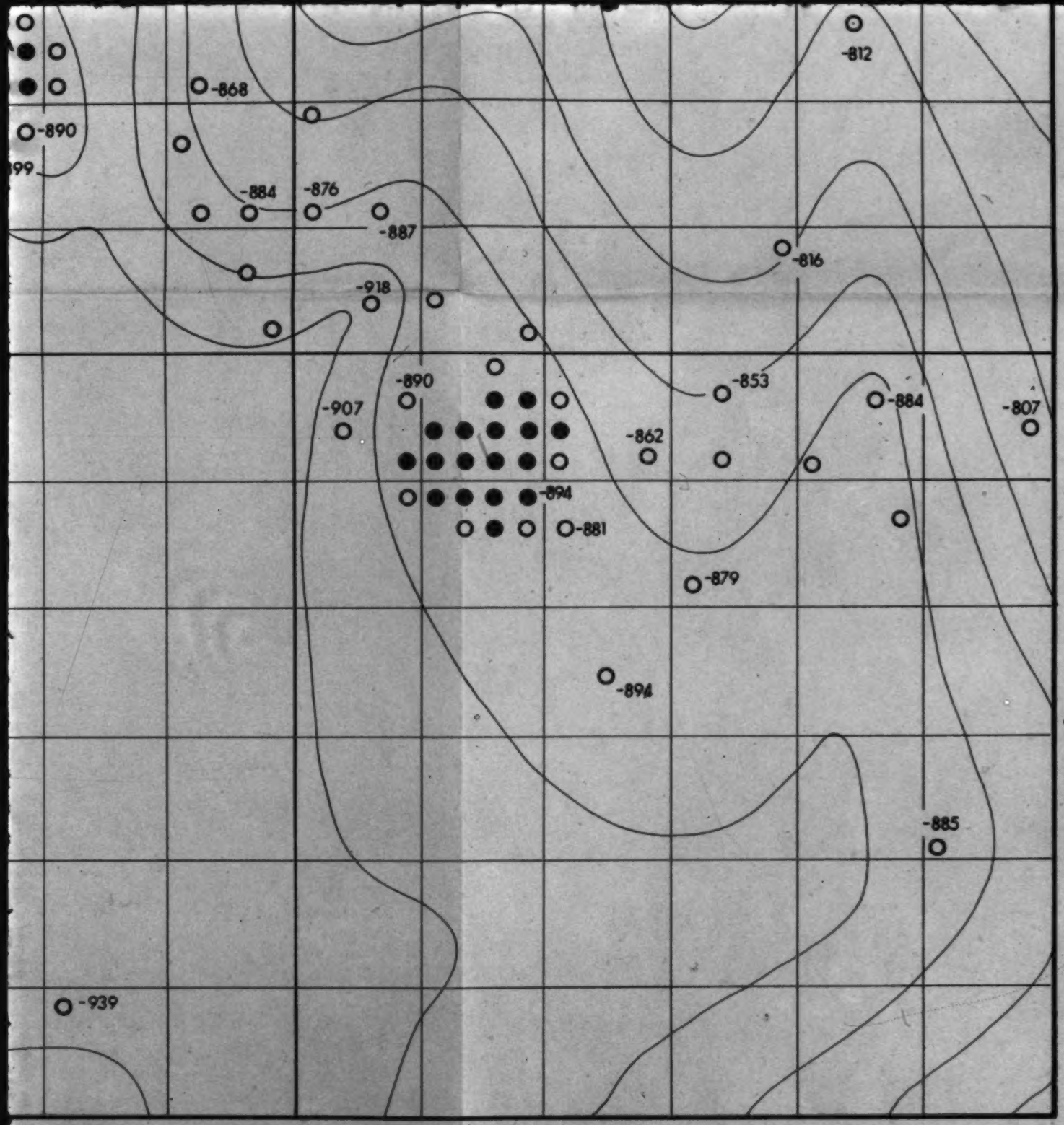
● Wells producing from the Mannville

○ Wells dry in the Mannville

G.L. Cartier,

Contour interval 2



Scale in miles

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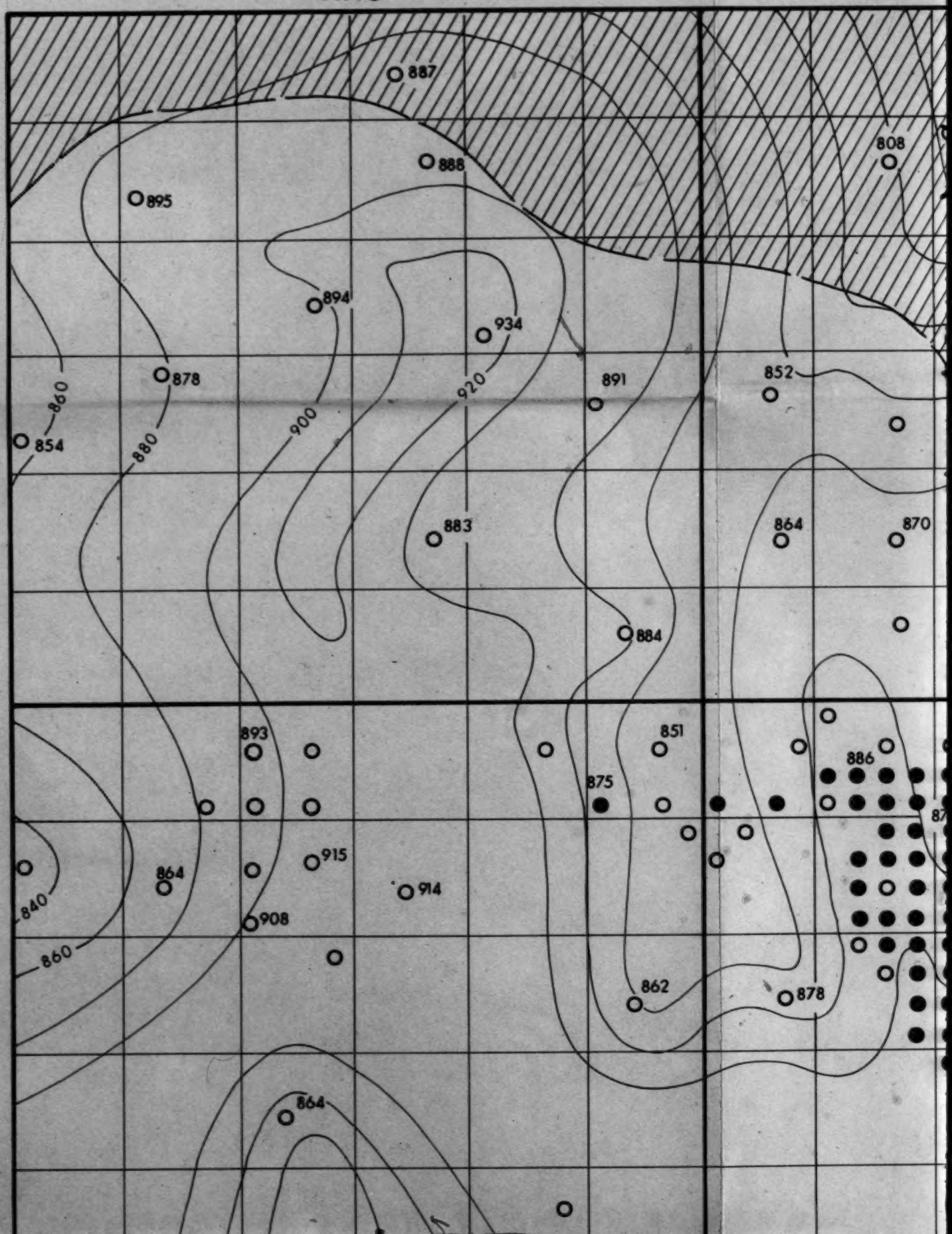
● Wells producing from the Mannville

○ Wells dry in the Mannville

G.L.Cartier, 1976.

Contour interval 25 feet.

6 of 6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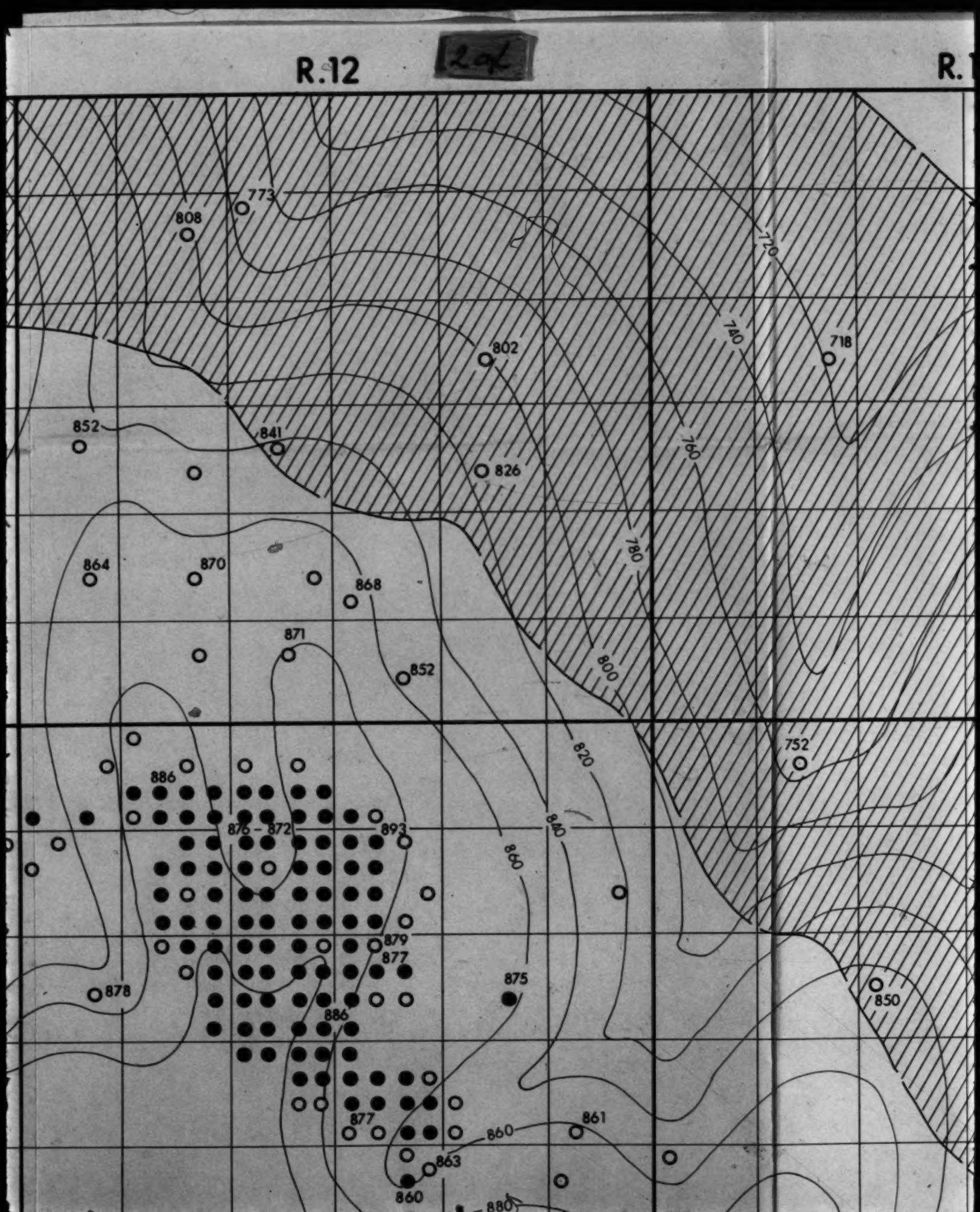
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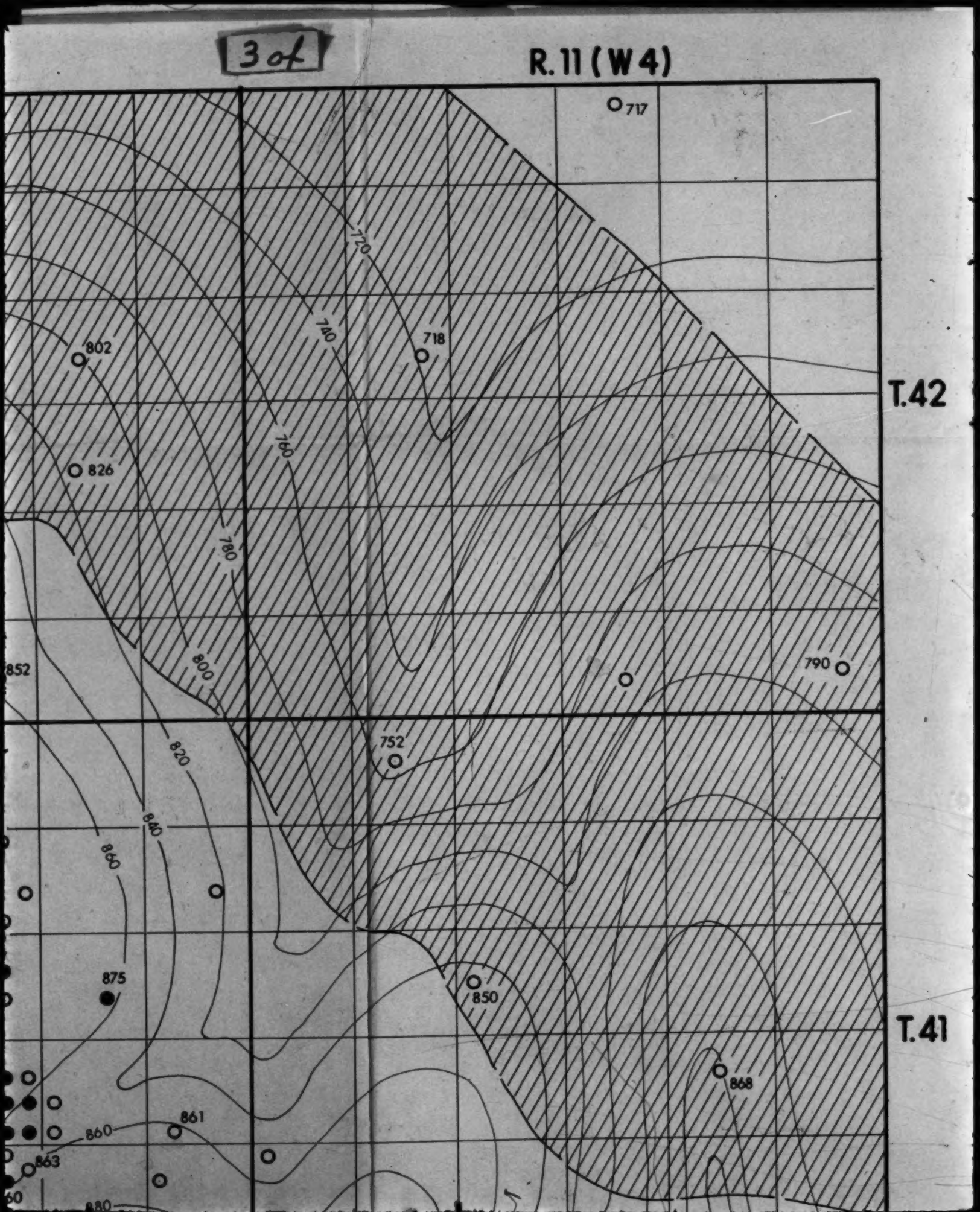
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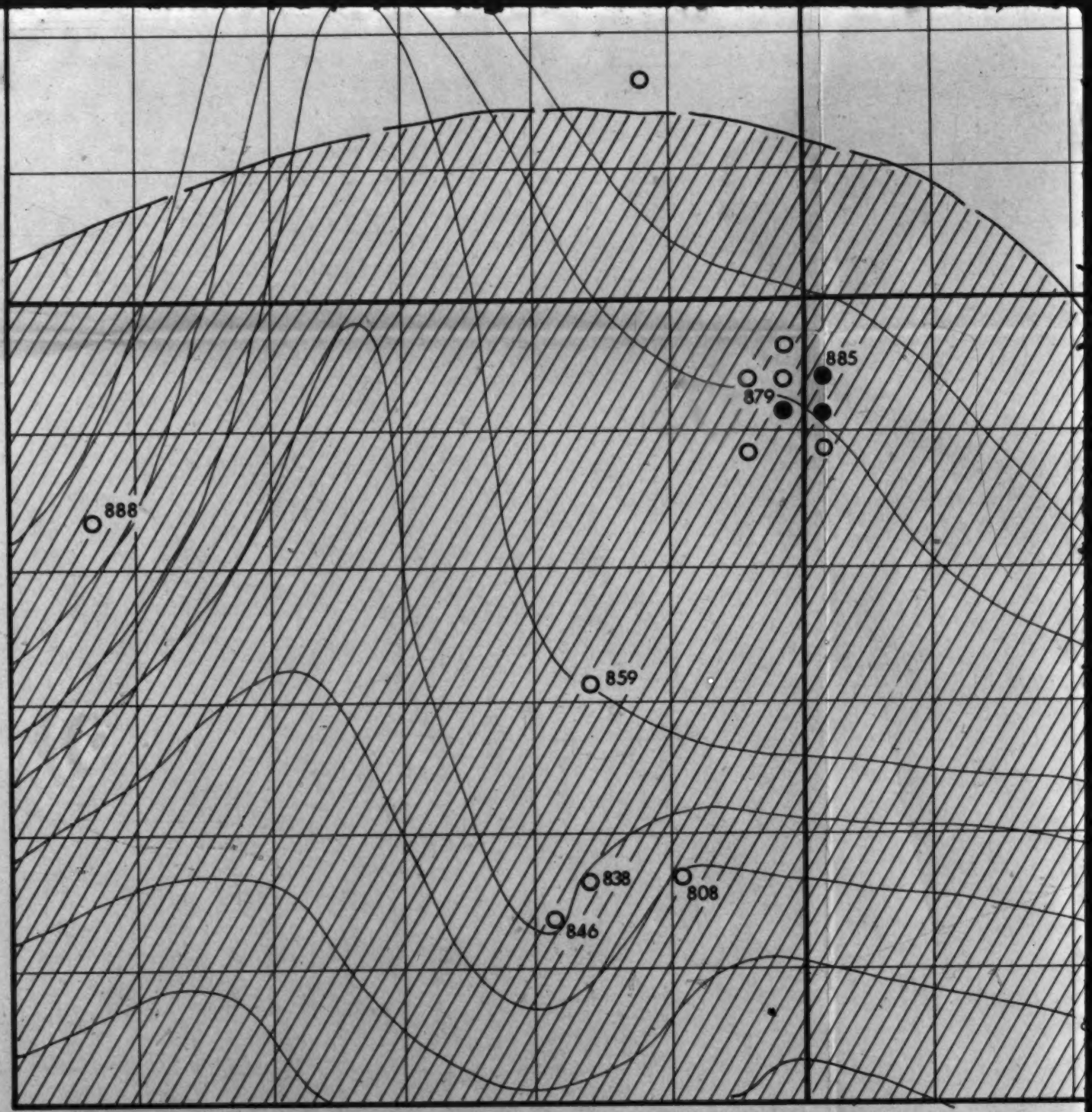
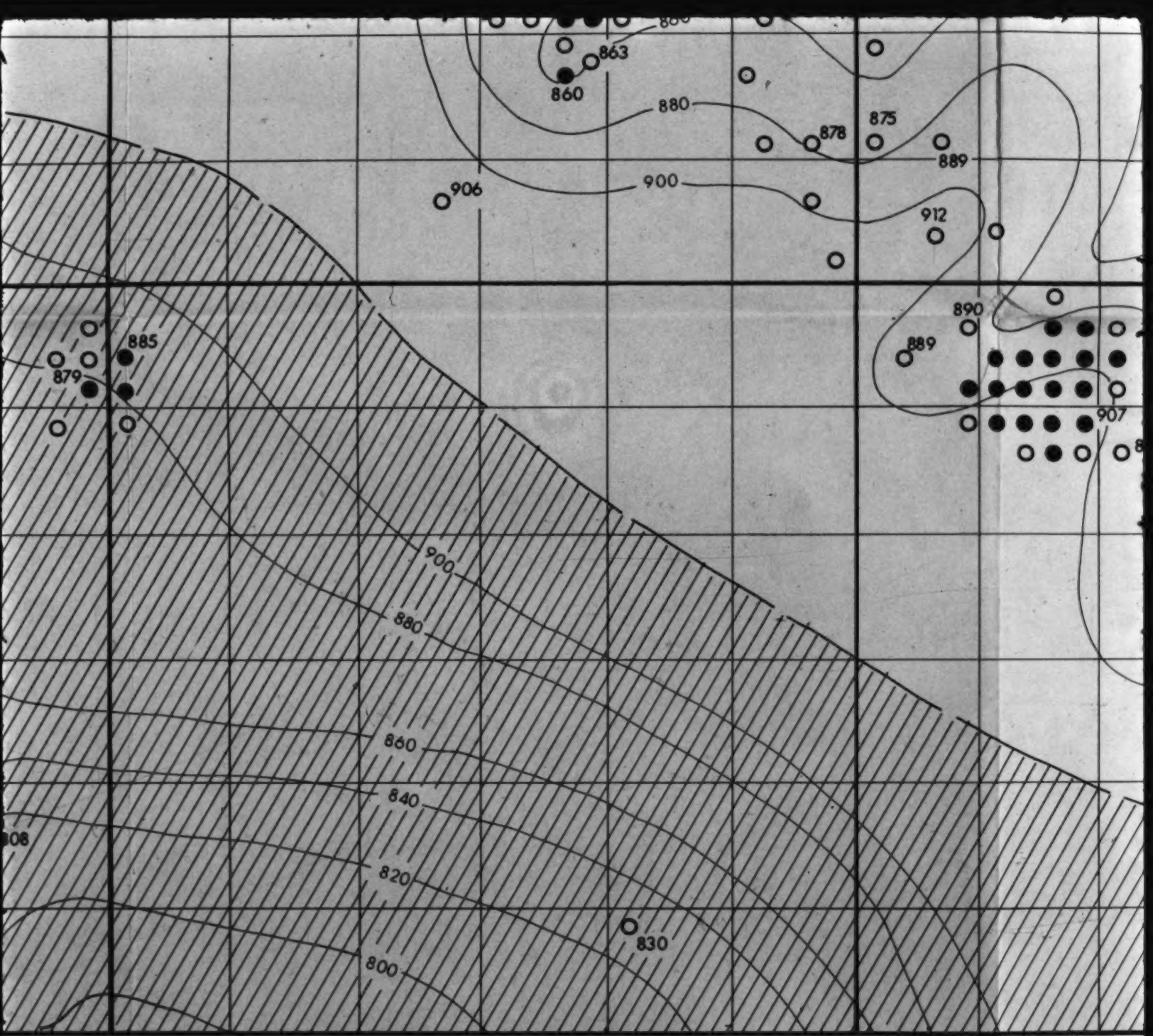


Figure 3.

LOWER CRETACEOUS ISOPACH MAP. (base of Fish Scale Marke
AND
PRE-MANNVILLE PALEOGEOLOGY MAP. (from Alberta
BELLSHILL LAKE AREA, ALBERTA.



Waban

Winterb

MAP. (base of Fish Scale Marker to Sub-Cretaceous unconformity)

GY MAP. (from Alberta O.G.C.B.)

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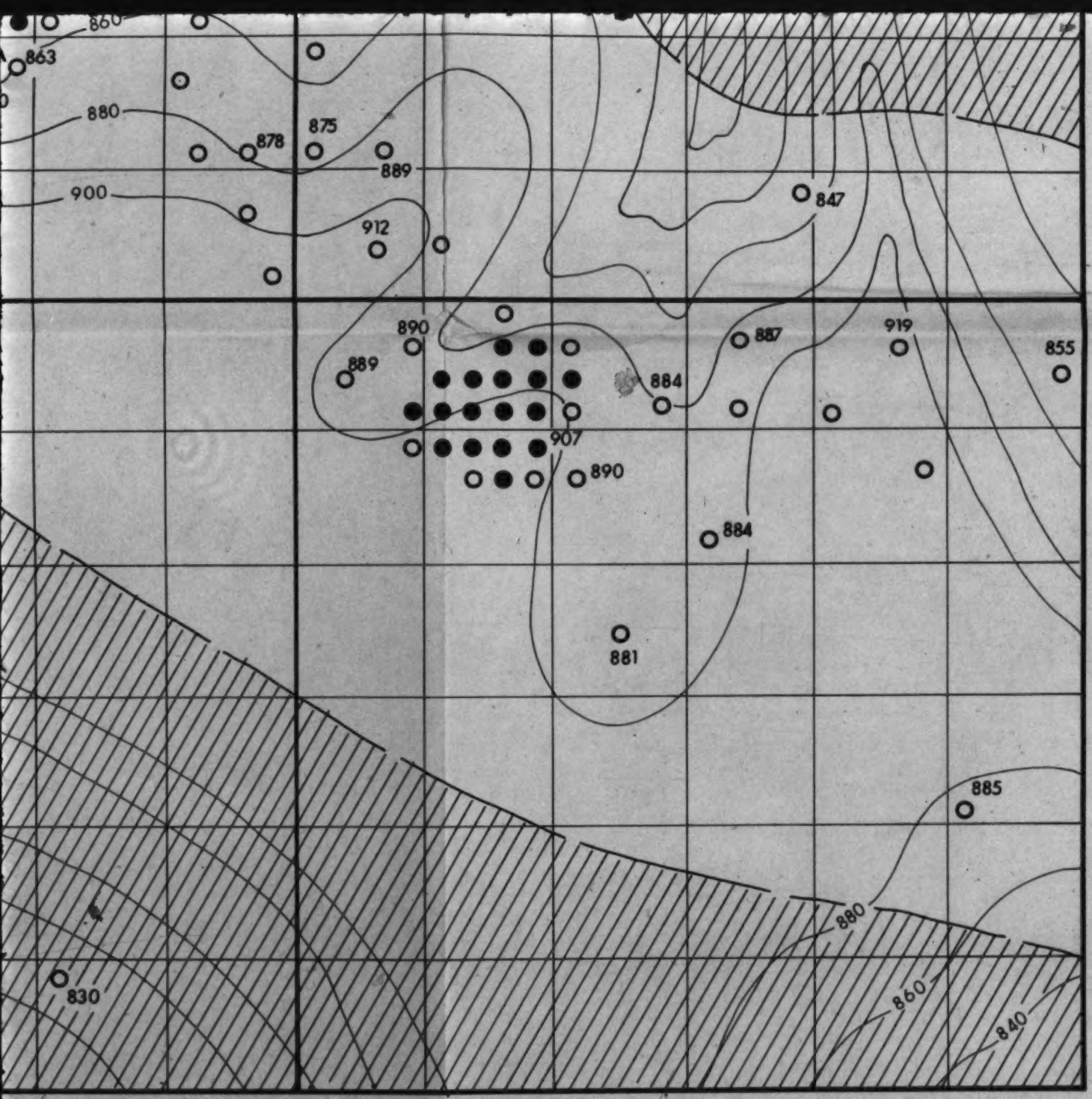
● Wells producing from the Mannville

○ Wells dry in the Mannville

G.L. Cart

Contour in



Wabamun Formation

Winterburn Formation

unconformity)

Scale in miles

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G.L. Cartier, 1976.

Contour interval 20 feet

lls producing from the Mannville

lls dry in the Mannville

6 of 6

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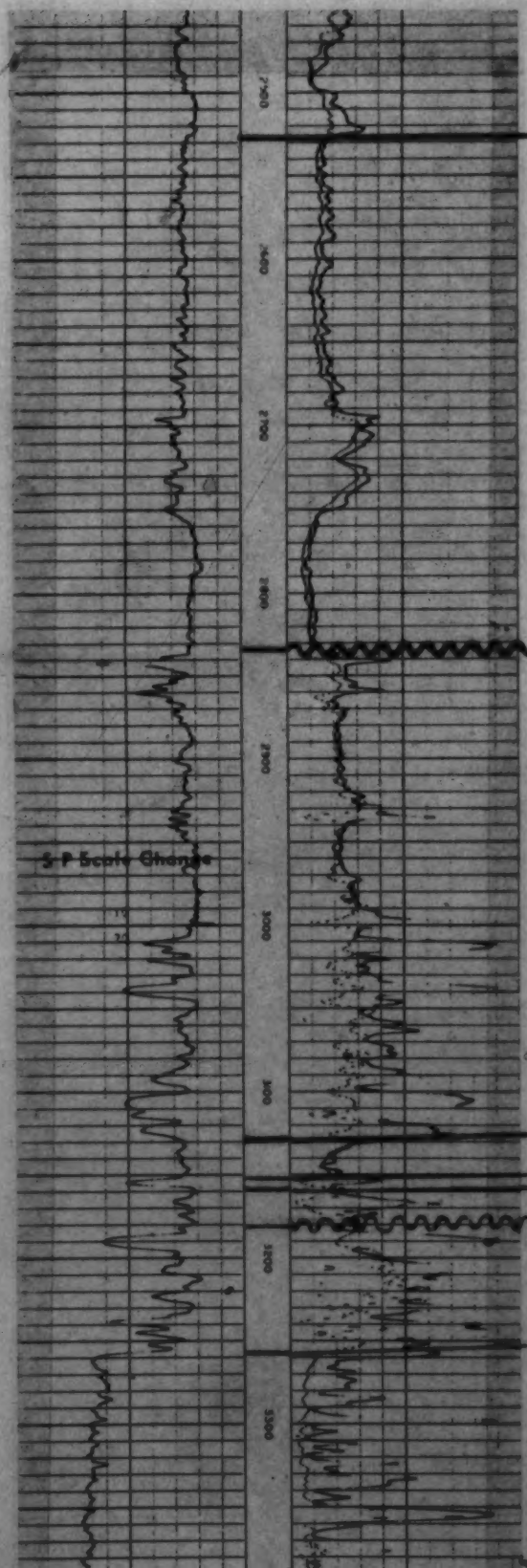
K.B. 2327



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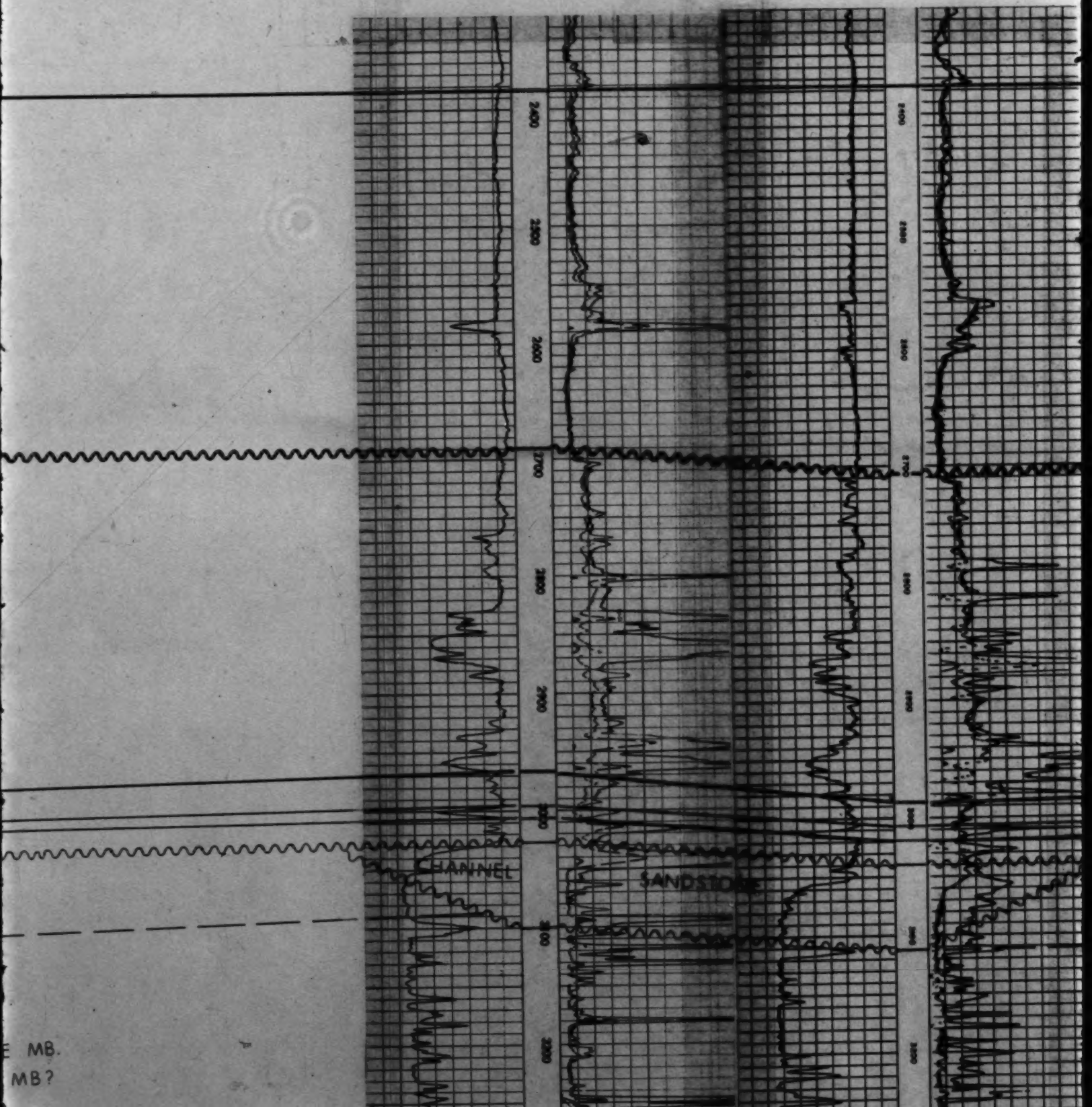
4-28-41-13W4
K.B. 2287

10-28-41-13 W4
K.B. 2289



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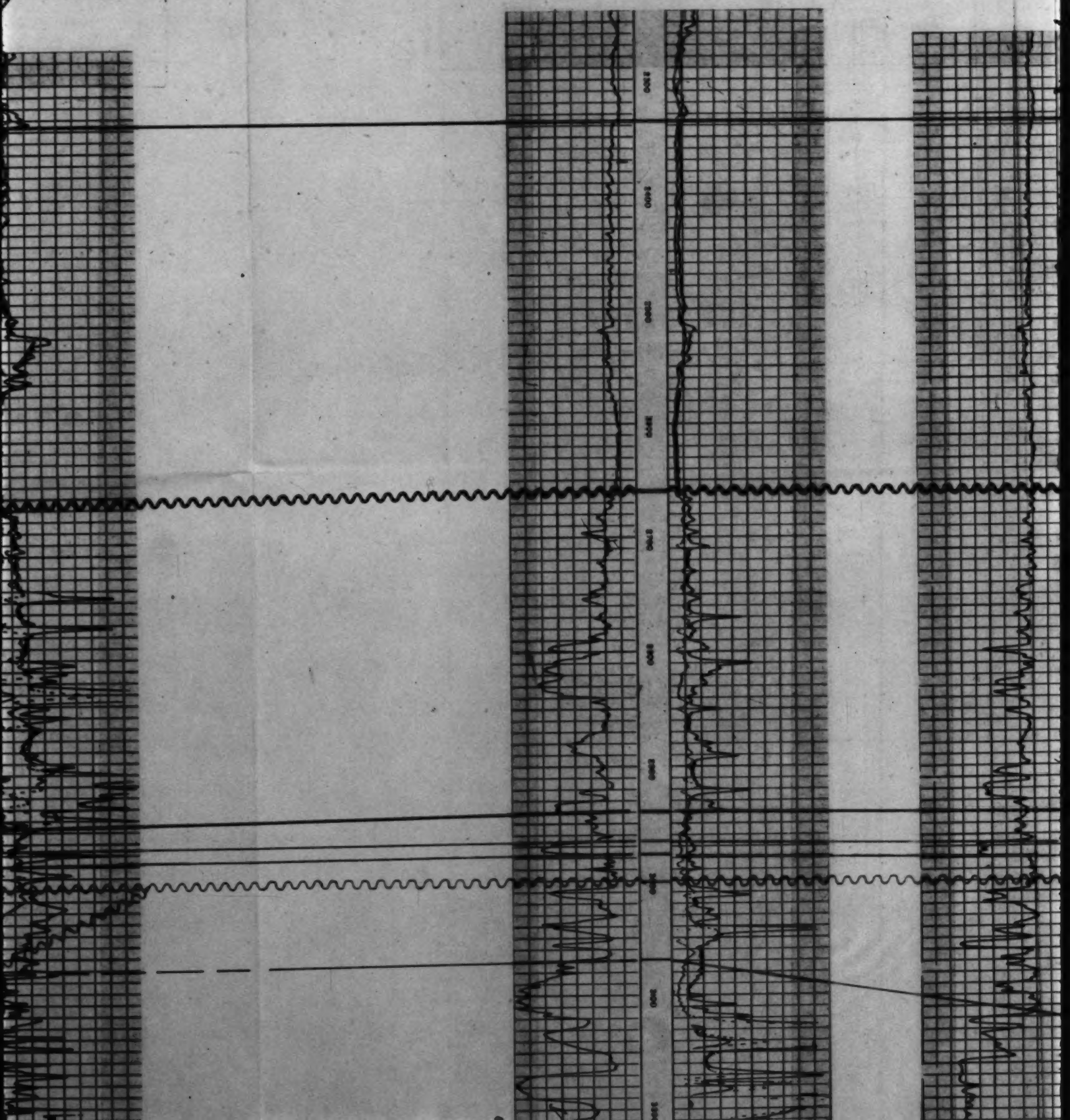
12-13-42
K.B.2



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10-18-42-12 W4
K.B. 2278

13-28
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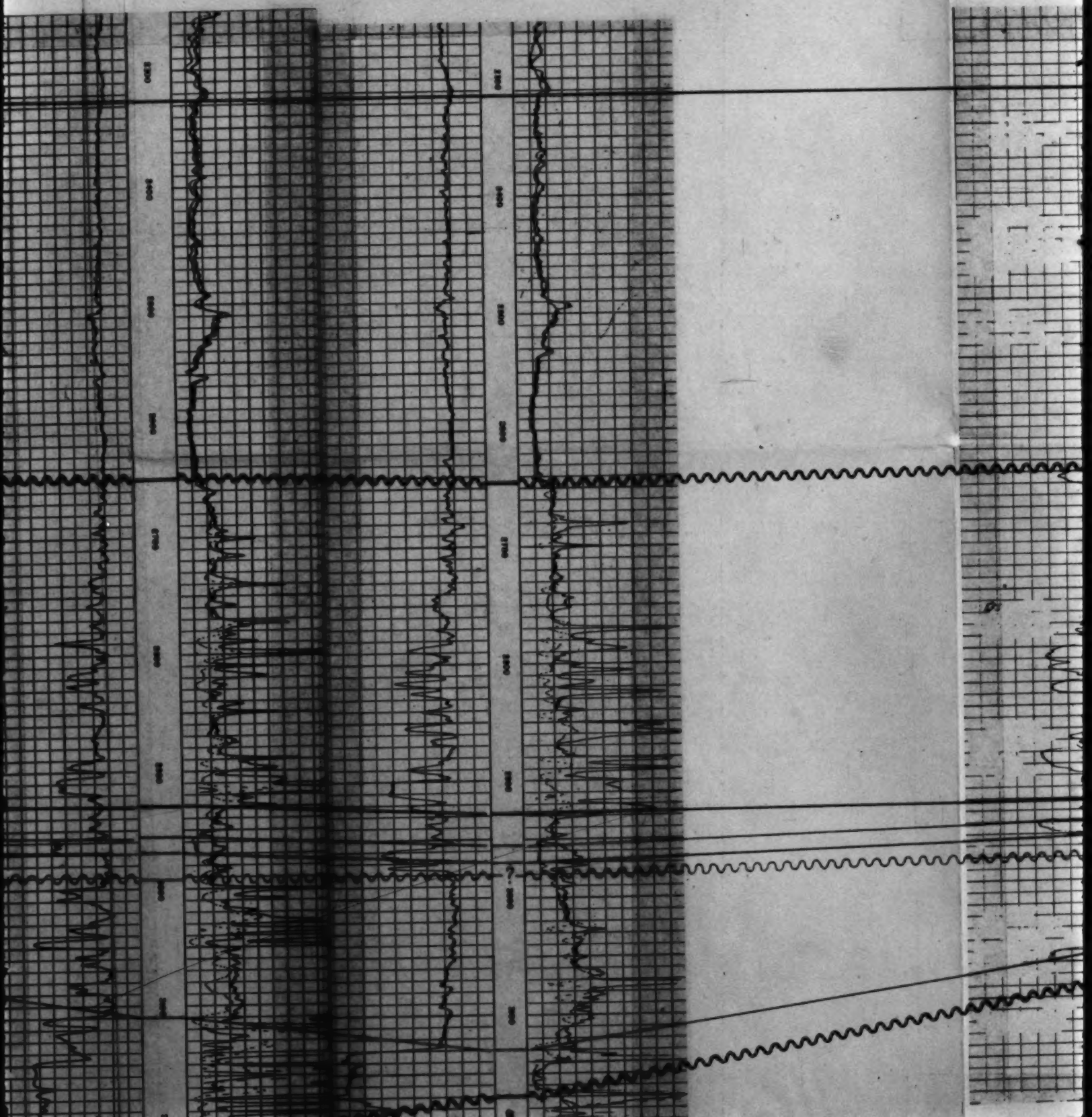

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K.B. 2350

10-9-43-12W4
K.B. 2286

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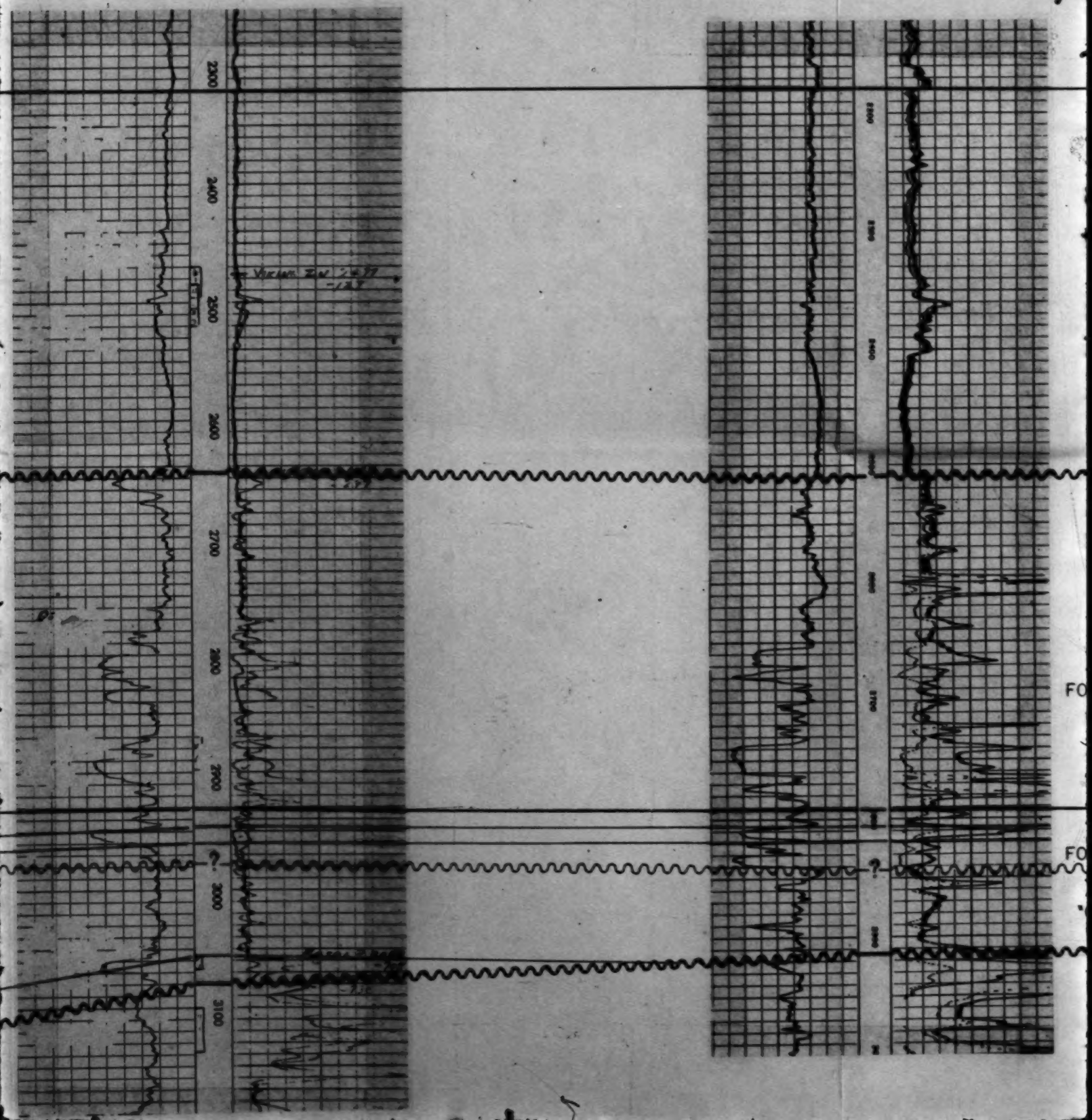

10-9-43-12W4
K.B. 2286

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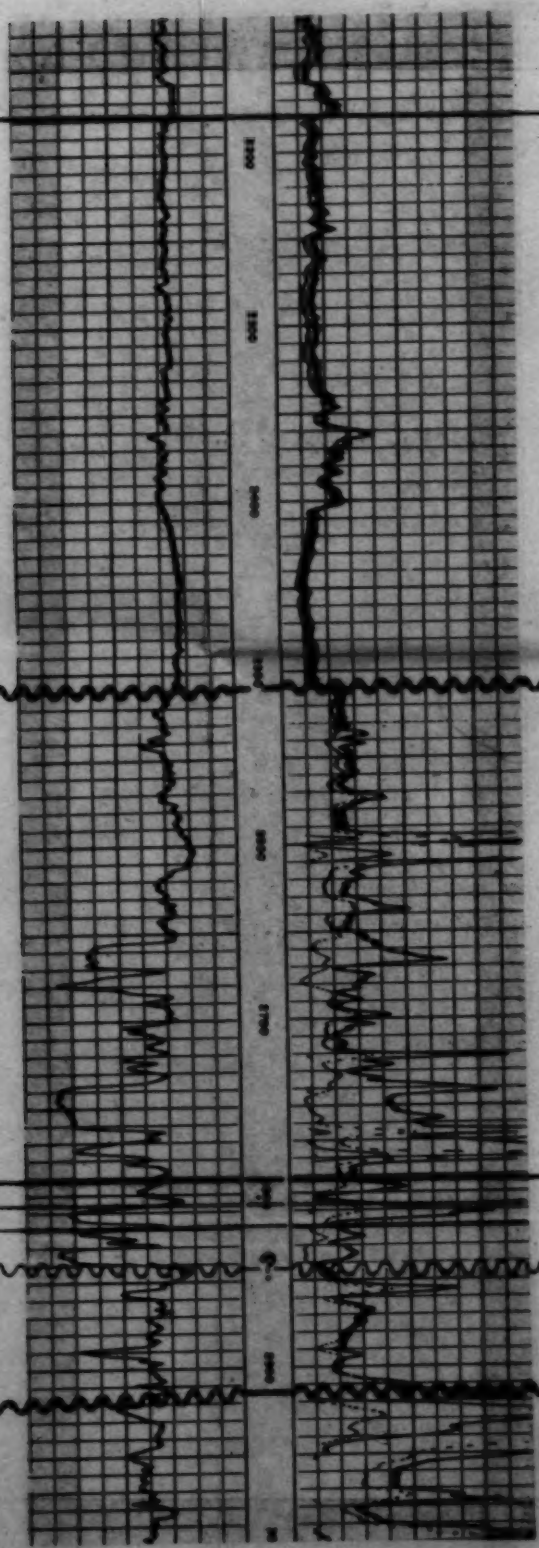

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LOWER CRETACEOUS

Mannville Group

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"CALCAREOUS" MB

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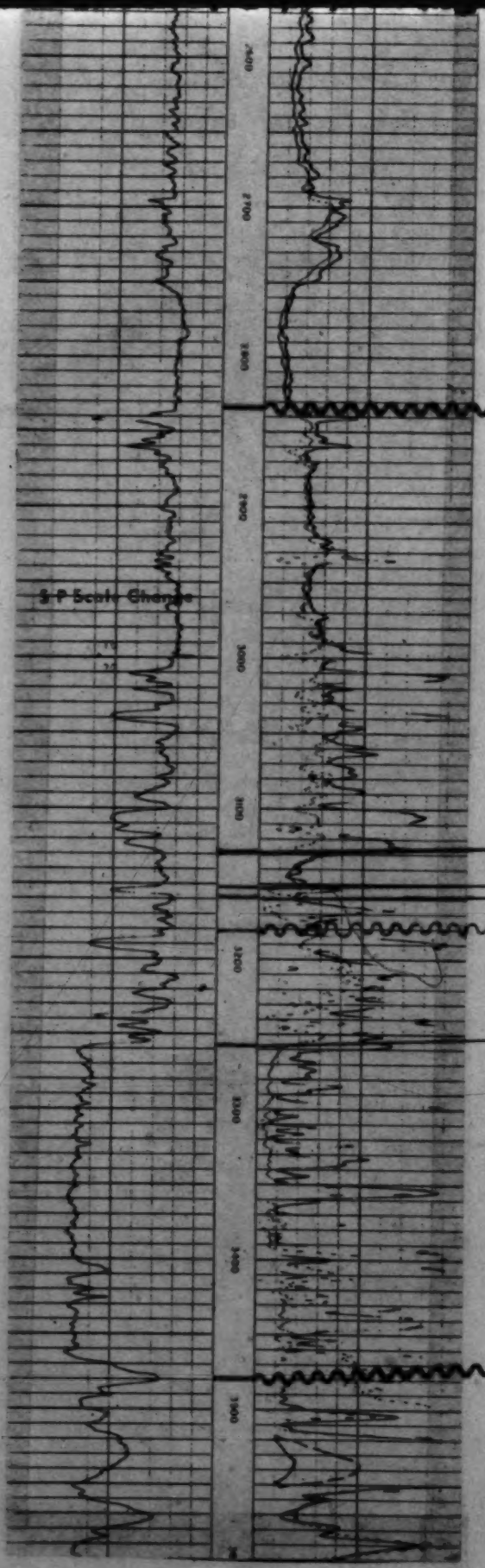

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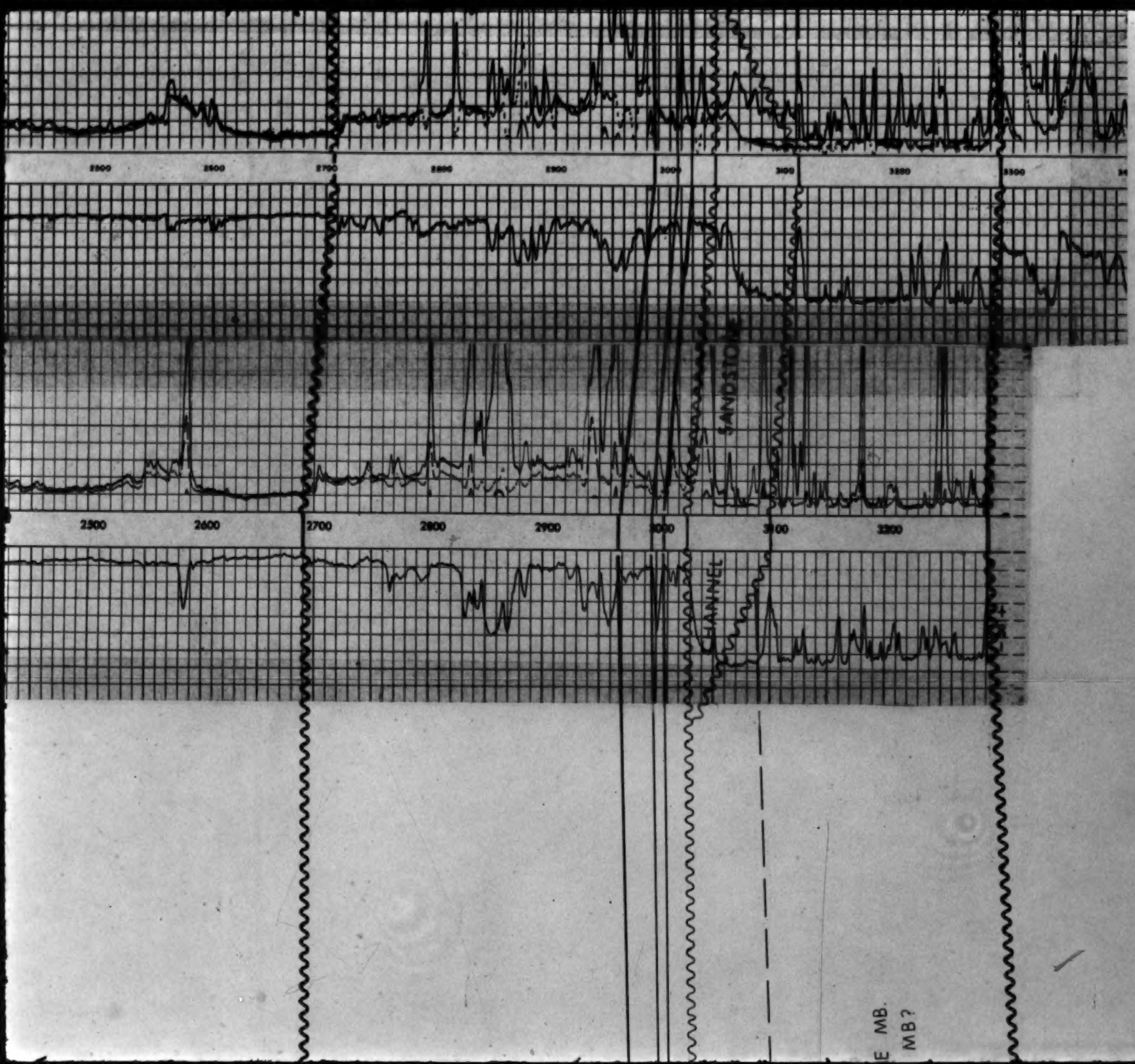
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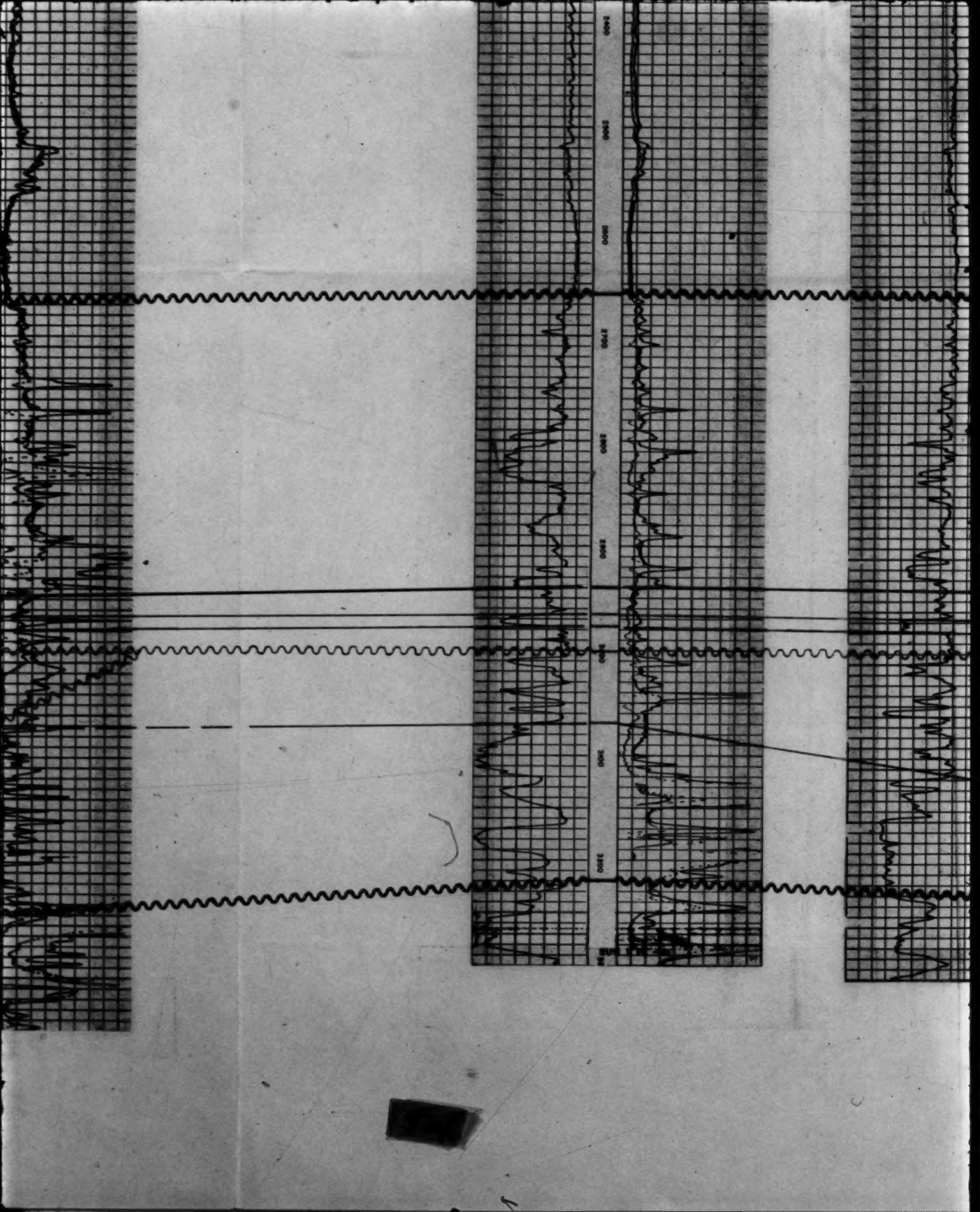

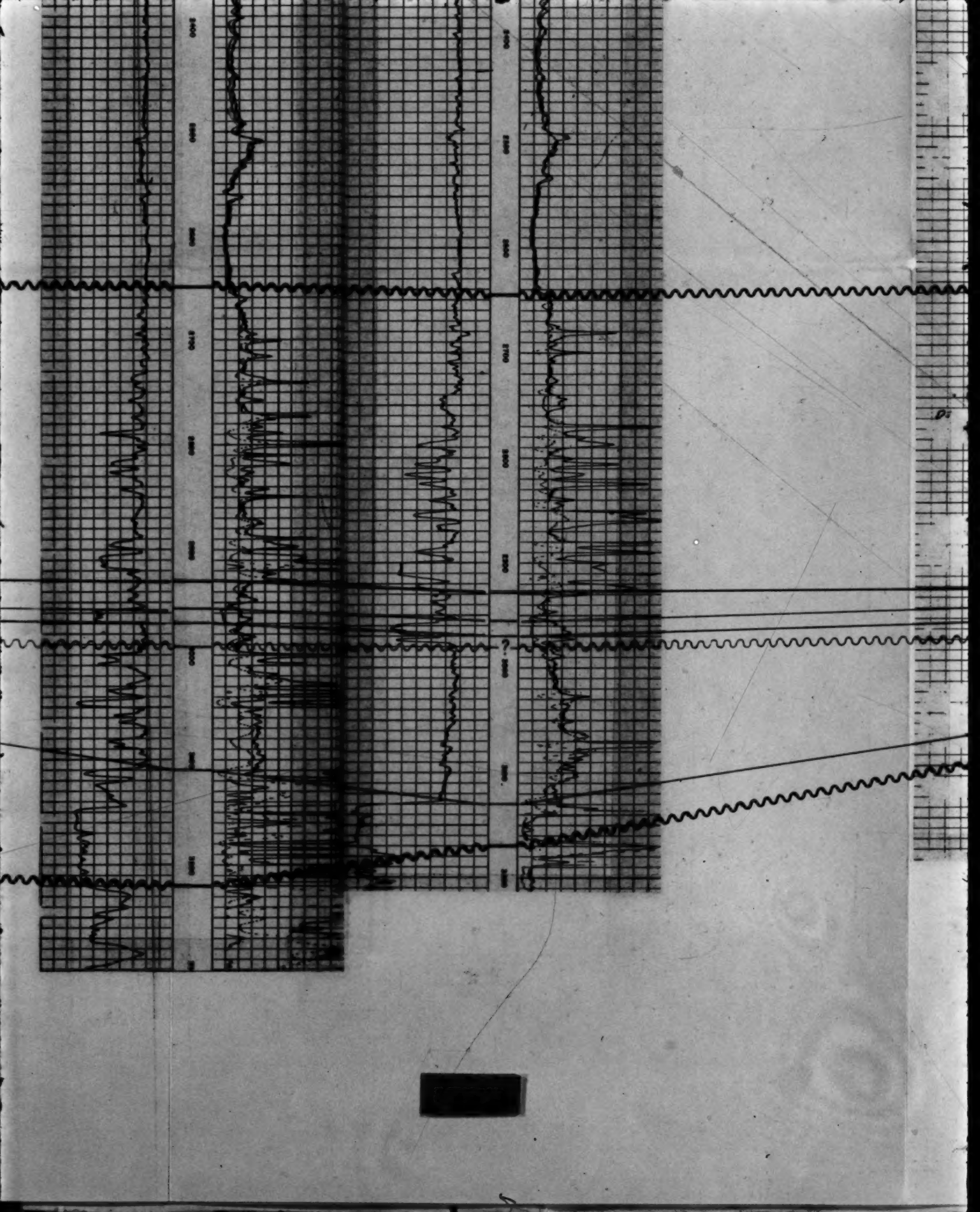

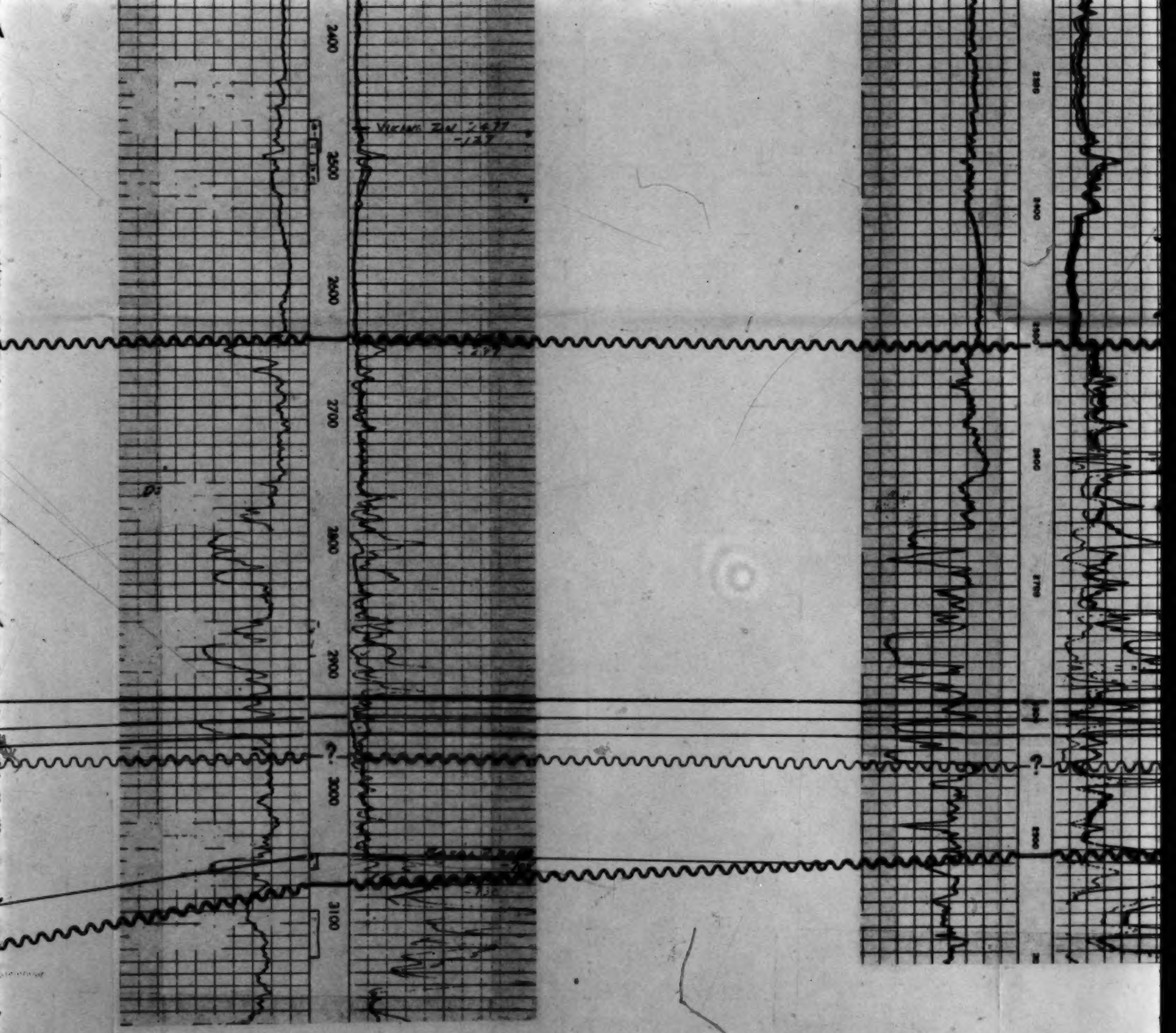

Figure

STRATIGRAPHIC CR

GALAHAD N°3 to KIDD CH

Vertical scale : 1" = 100 ft., Horiz
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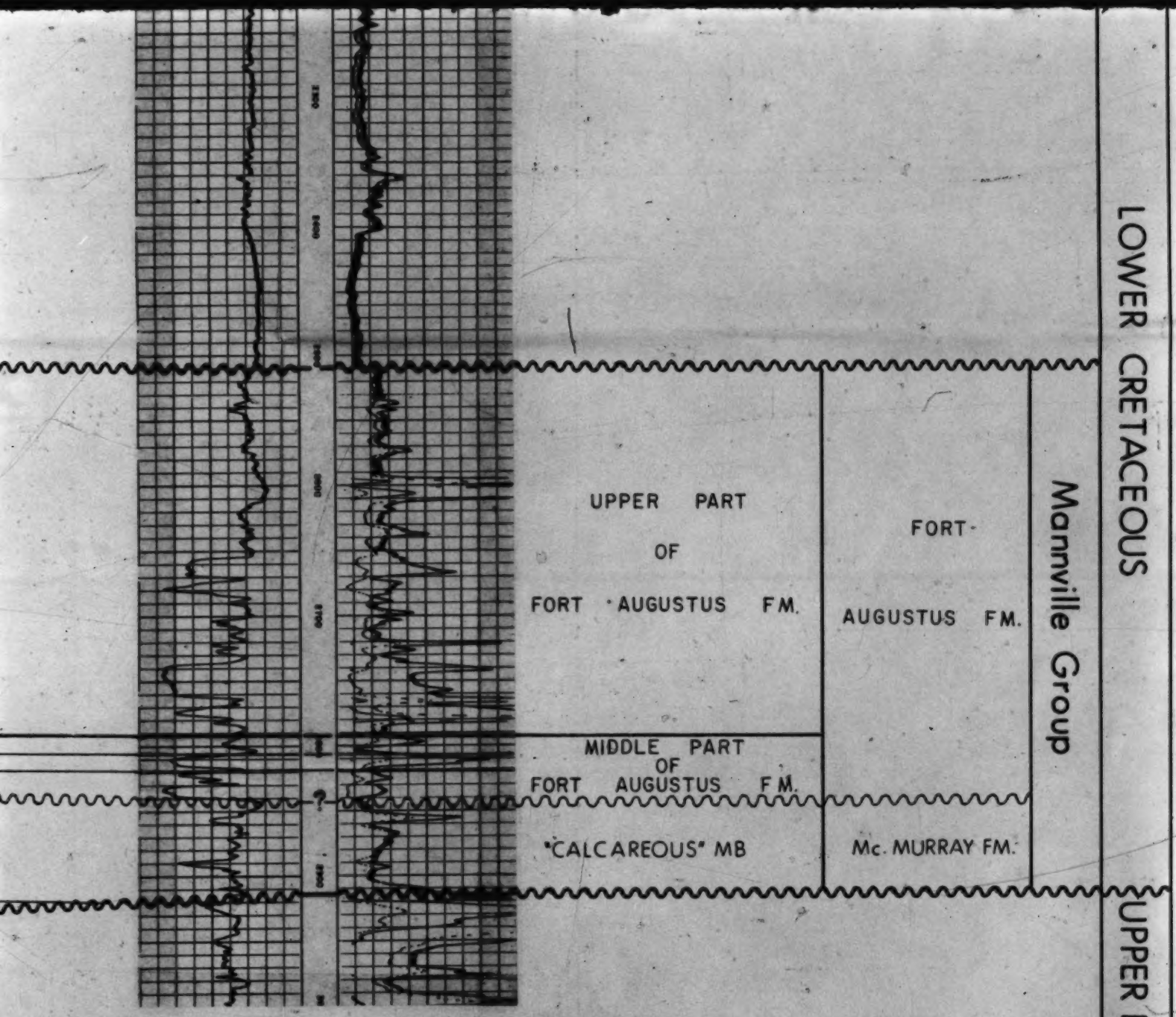


Figure 4.

STRATIGRAPHIC CROSS SECTION I.

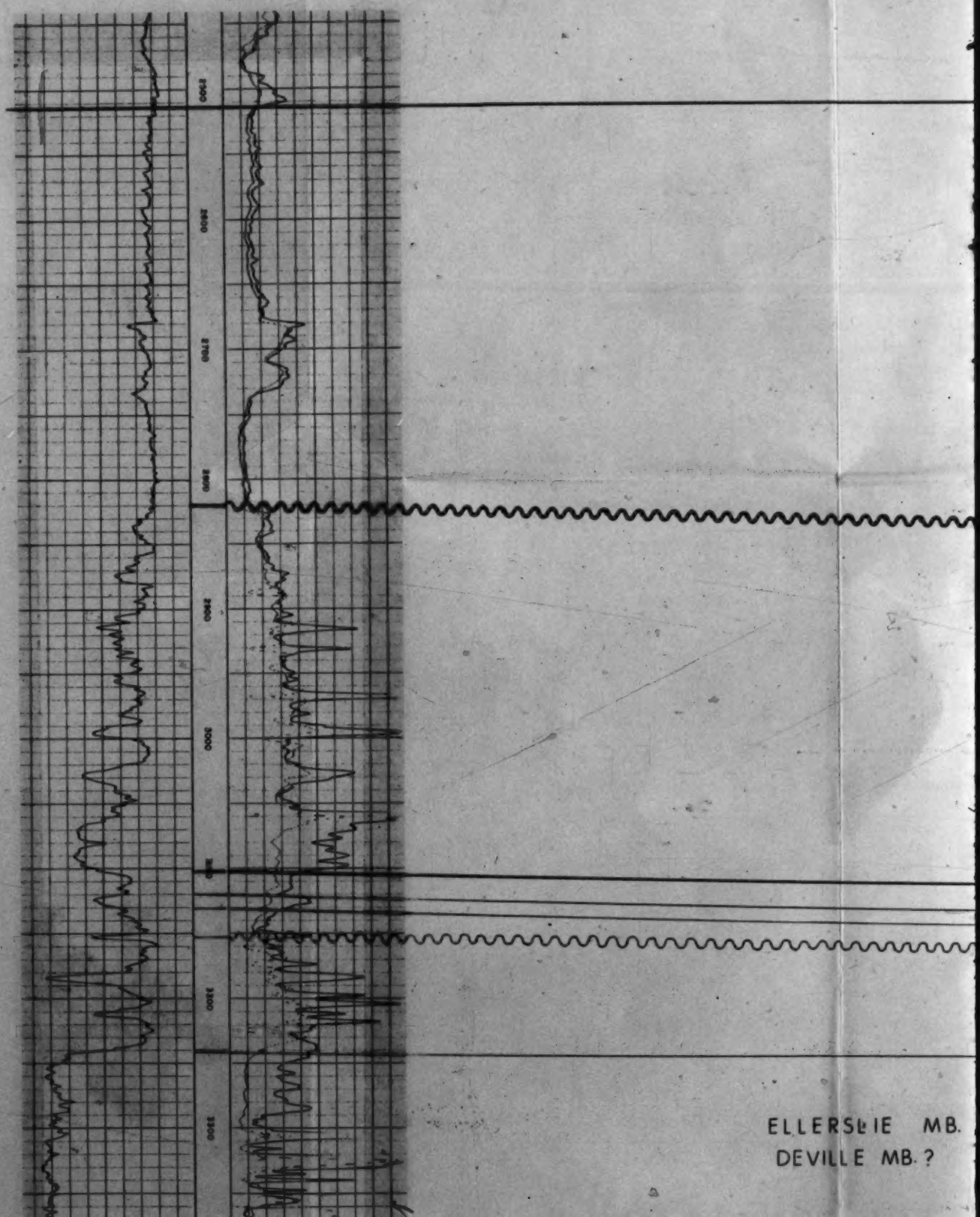
GALAHAD N°3 to KIDD CHARTER SEDGEWICK N°10-9

Vertical scale : 1" = 100 ft., Horizontal scale : 1" = 0·5 mi. (exept when the distance between two wells is less than 1·57 mile.)

G.L. Cartier, 1976

B

7-30-40-13W4
K. B. 2323



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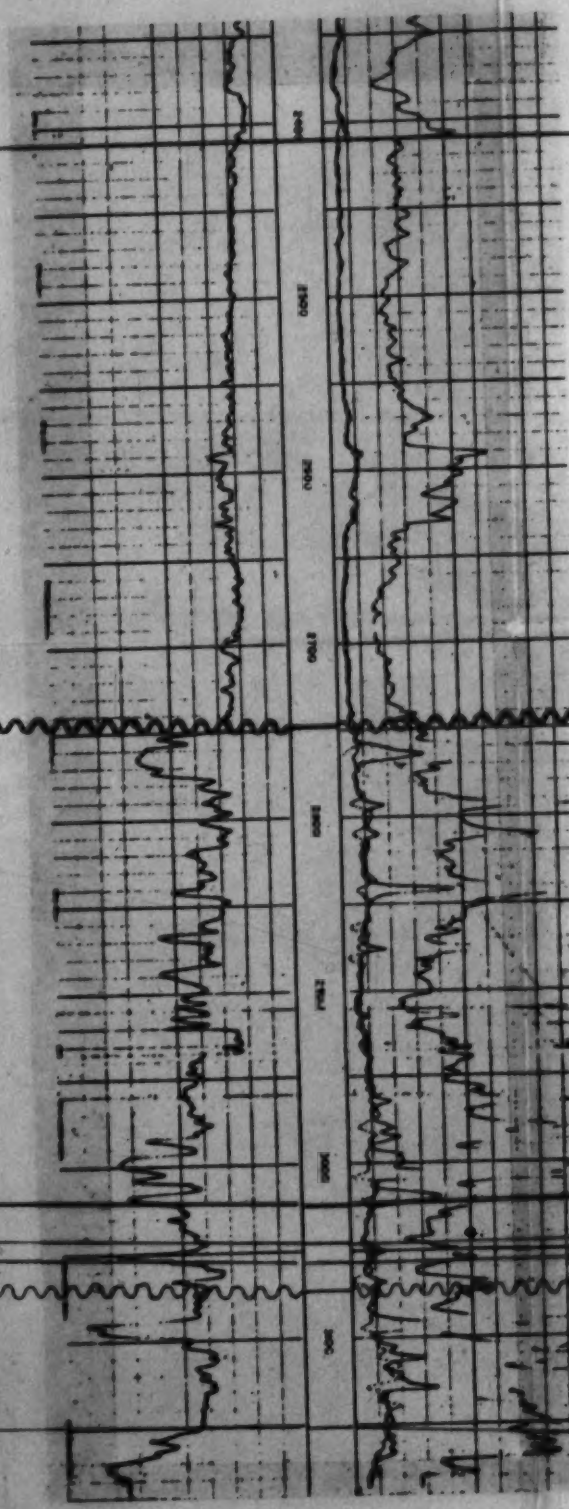

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2-29-41-12W4
K.B. 2296

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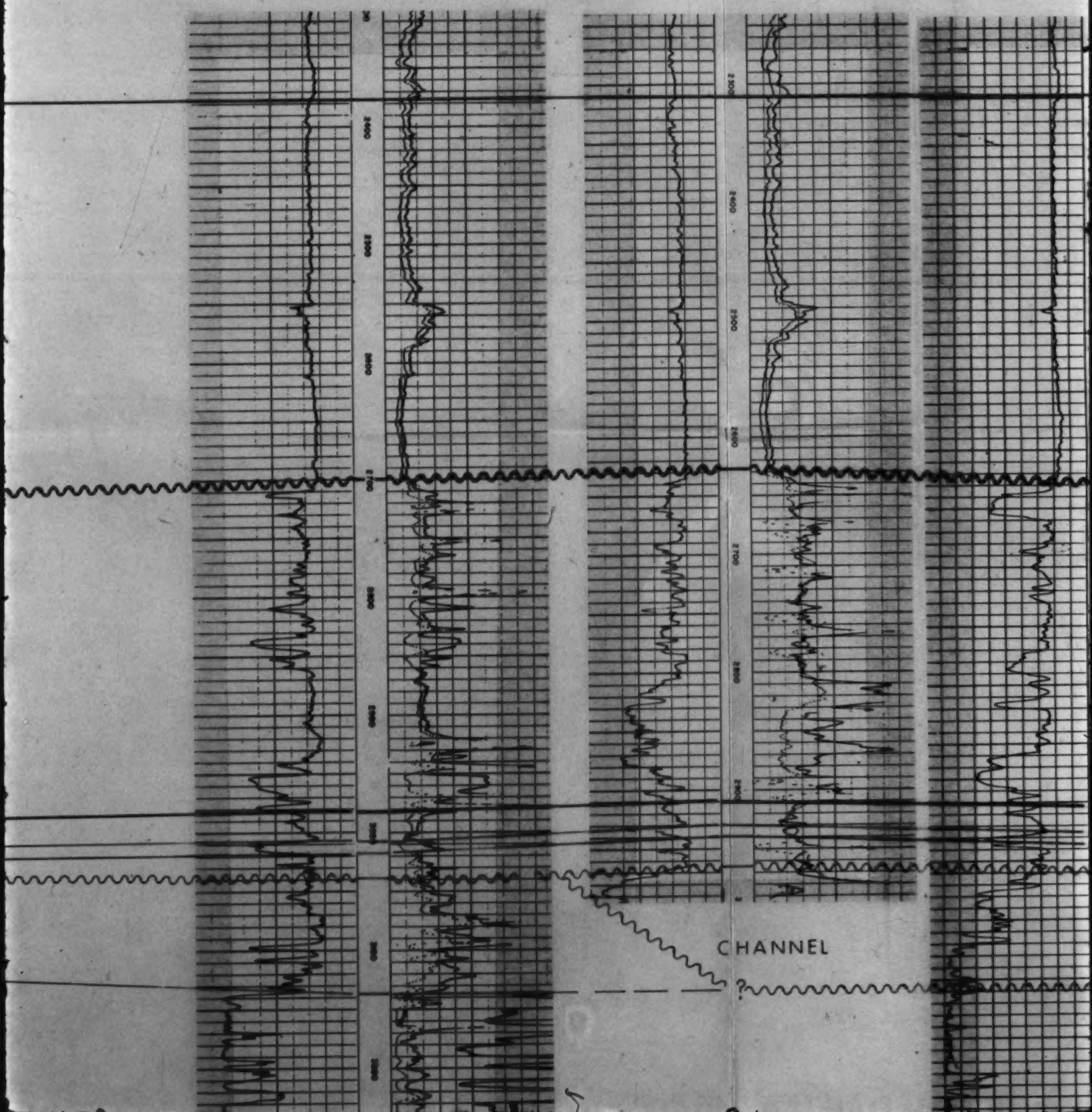

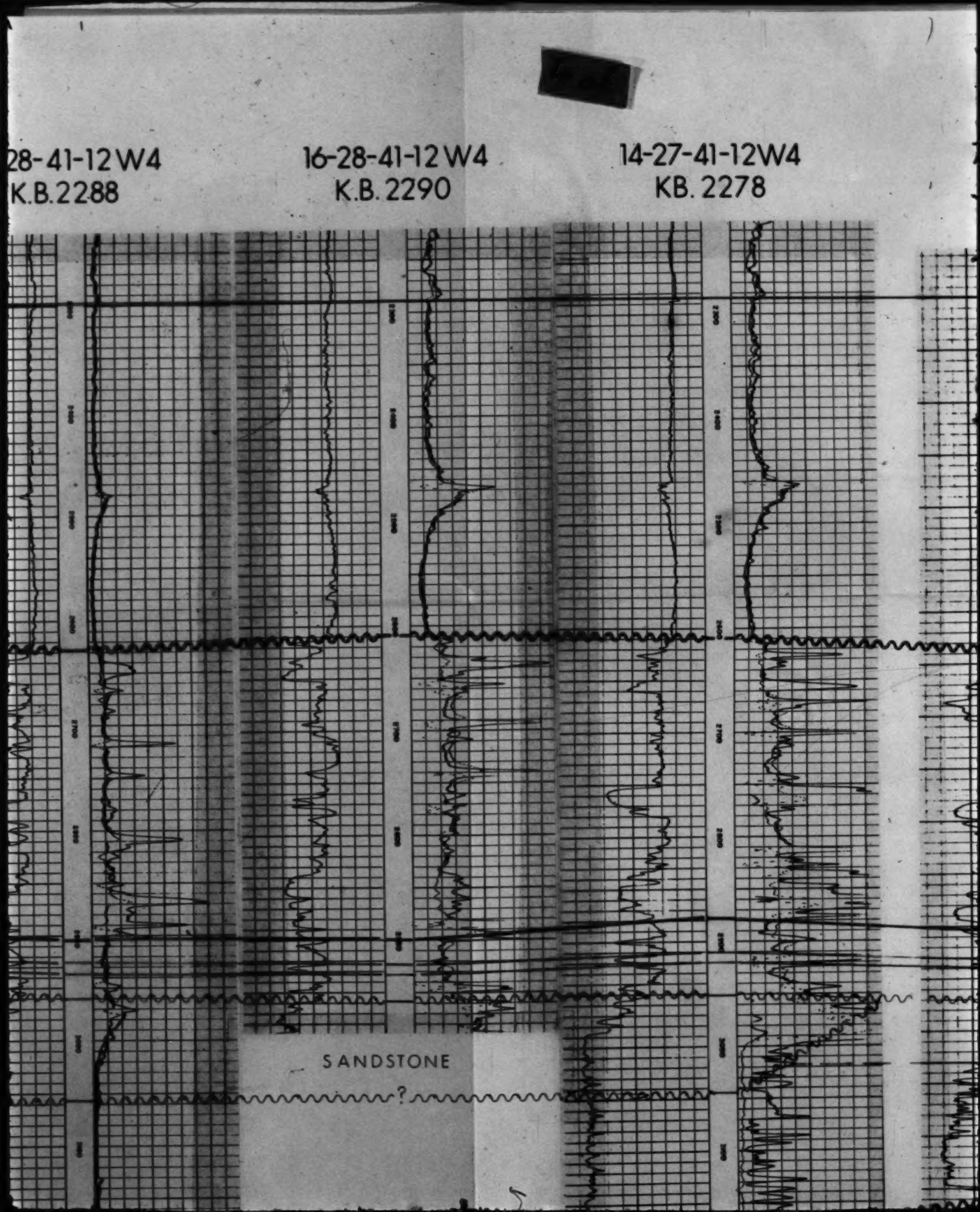
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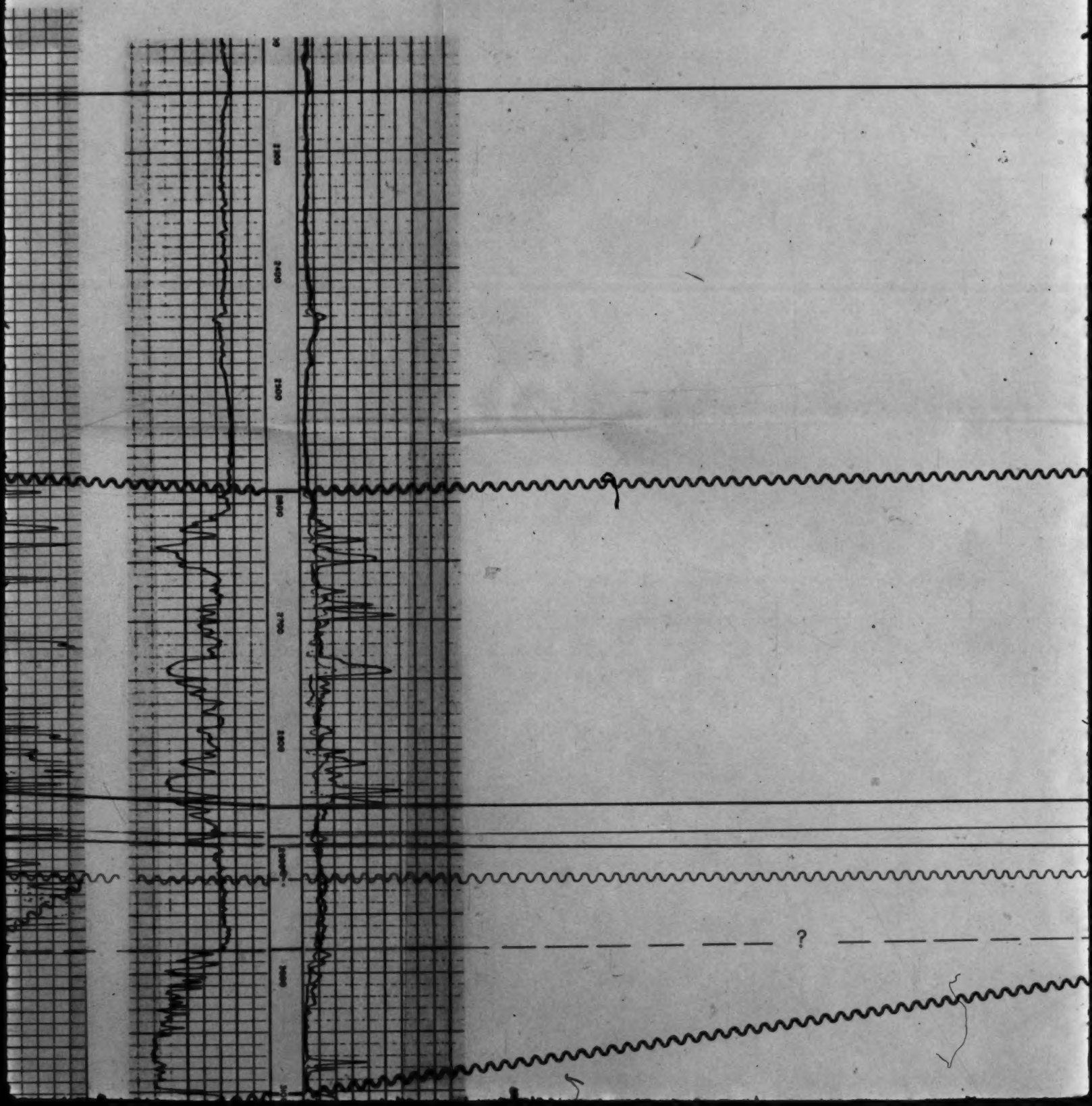

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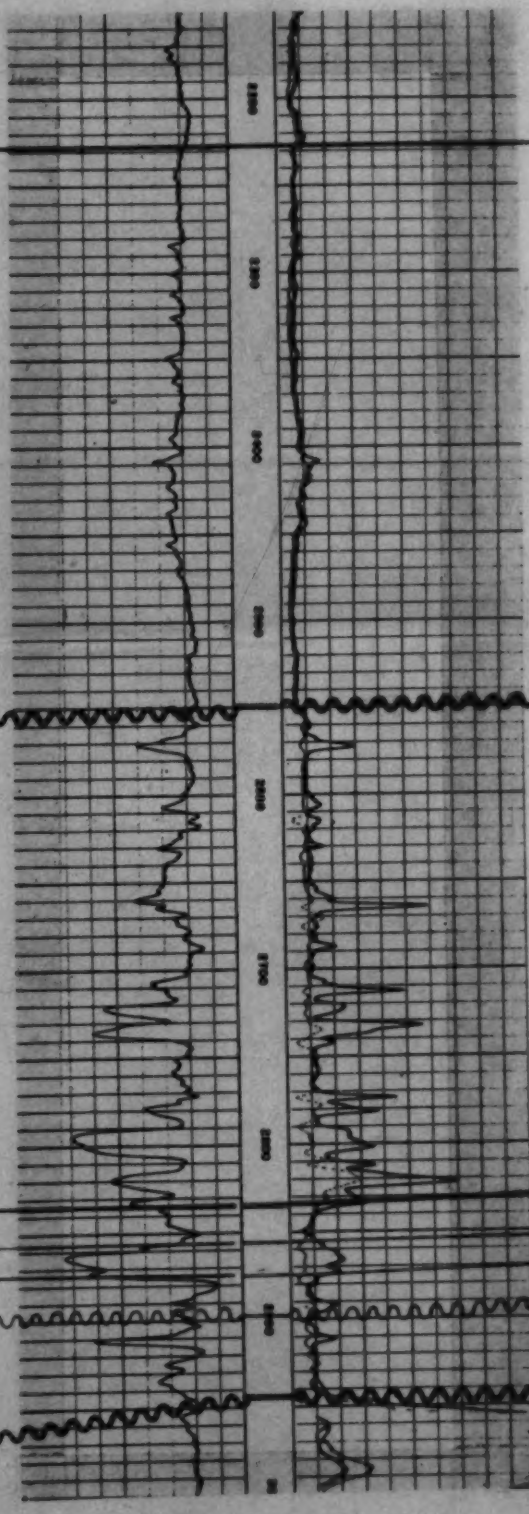
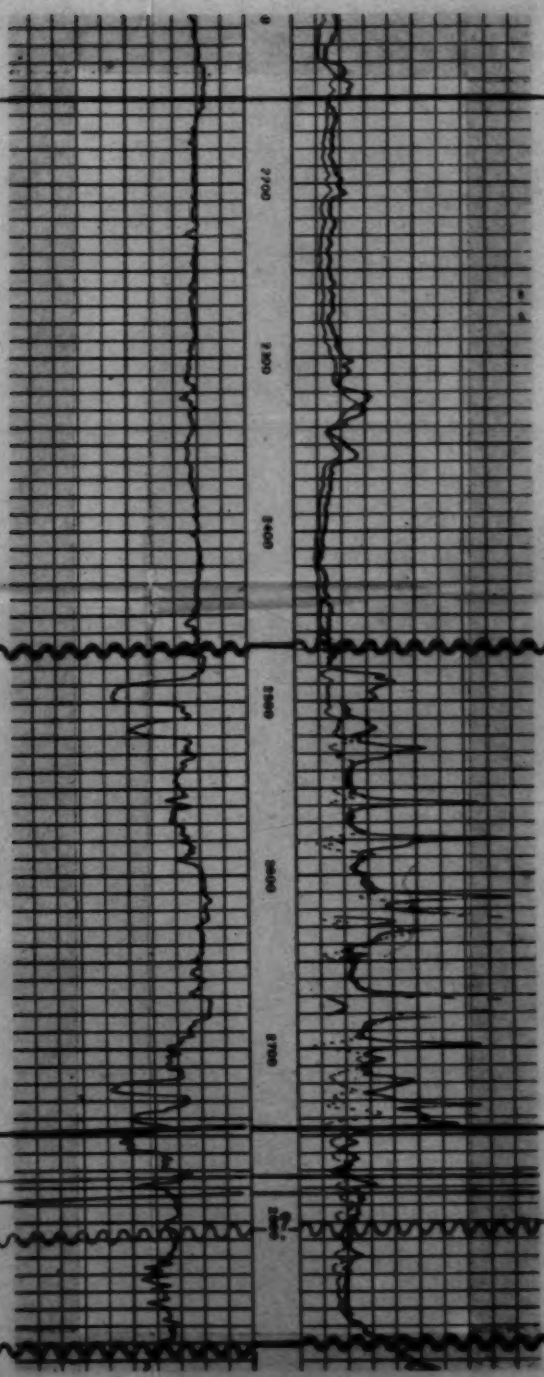


15-34-42-11 W4
K.B. 2283

B'



Datum : base of Fish Scale Marker

UPPER PART OF FORT AUGUSTUS FM.

MIDDLE PART OF FORT AUGUSTUS FM.

"CALCAREOUS" MB.

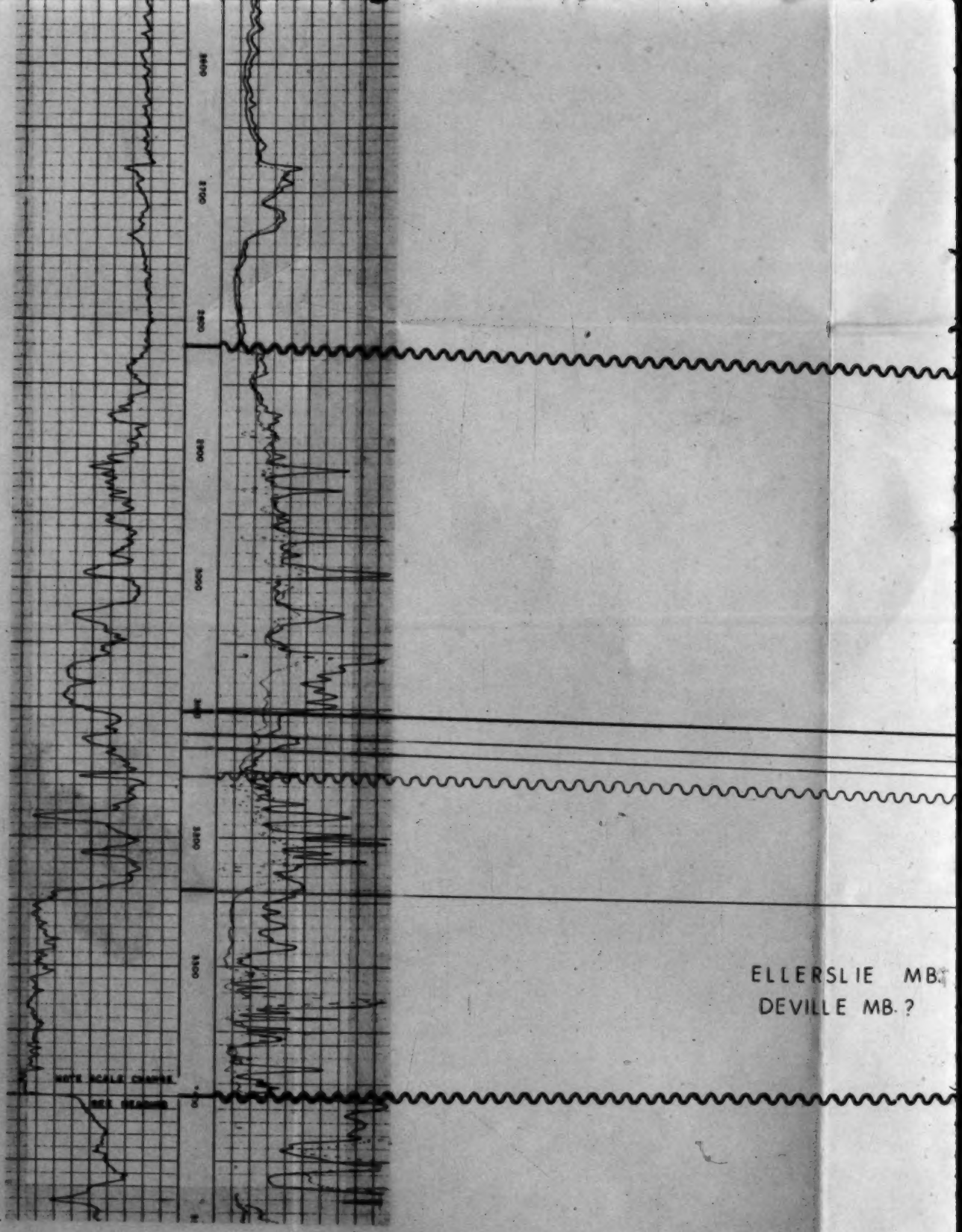
FORT AUGUSTUS FM.

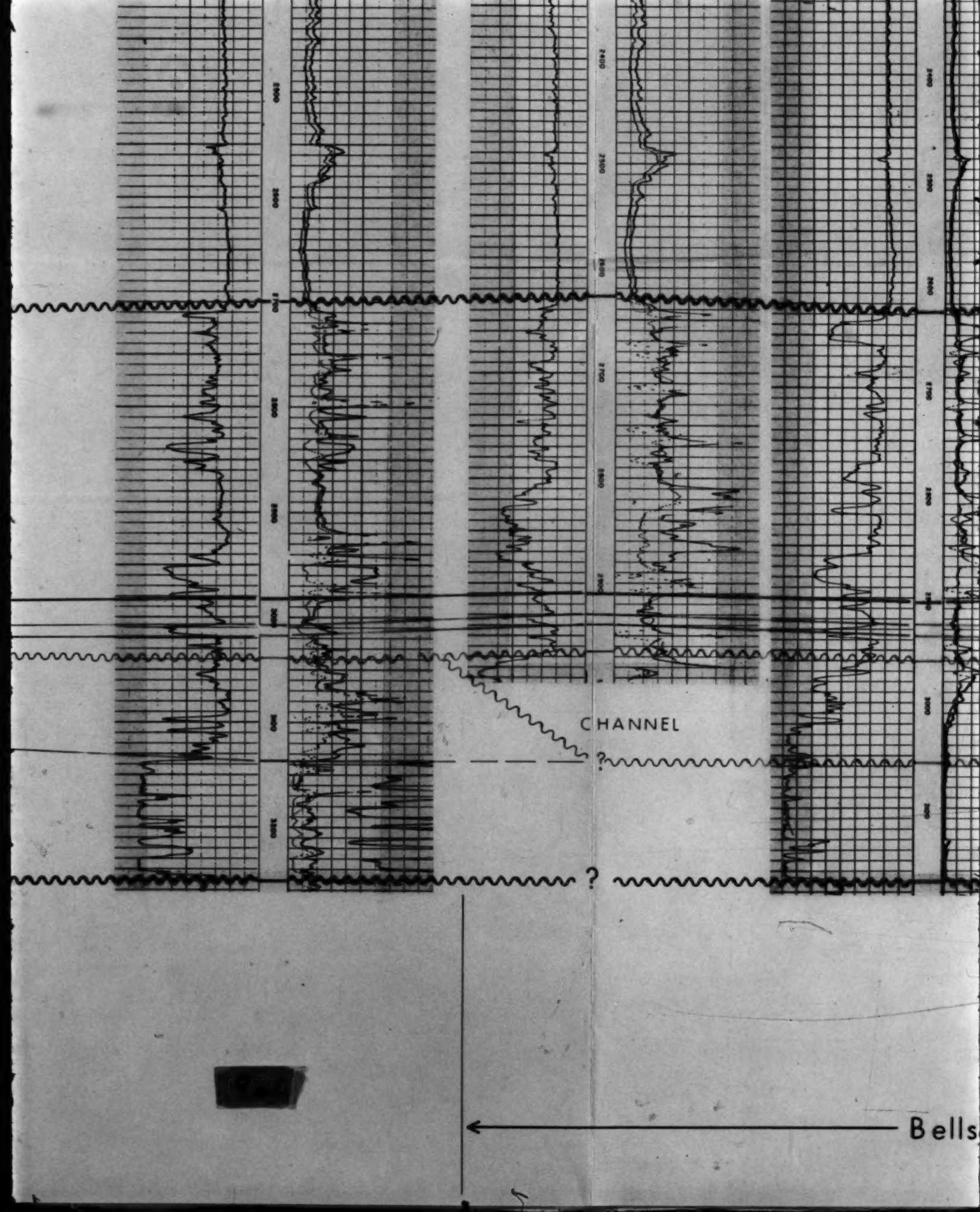
Mc. MURRAY FM.

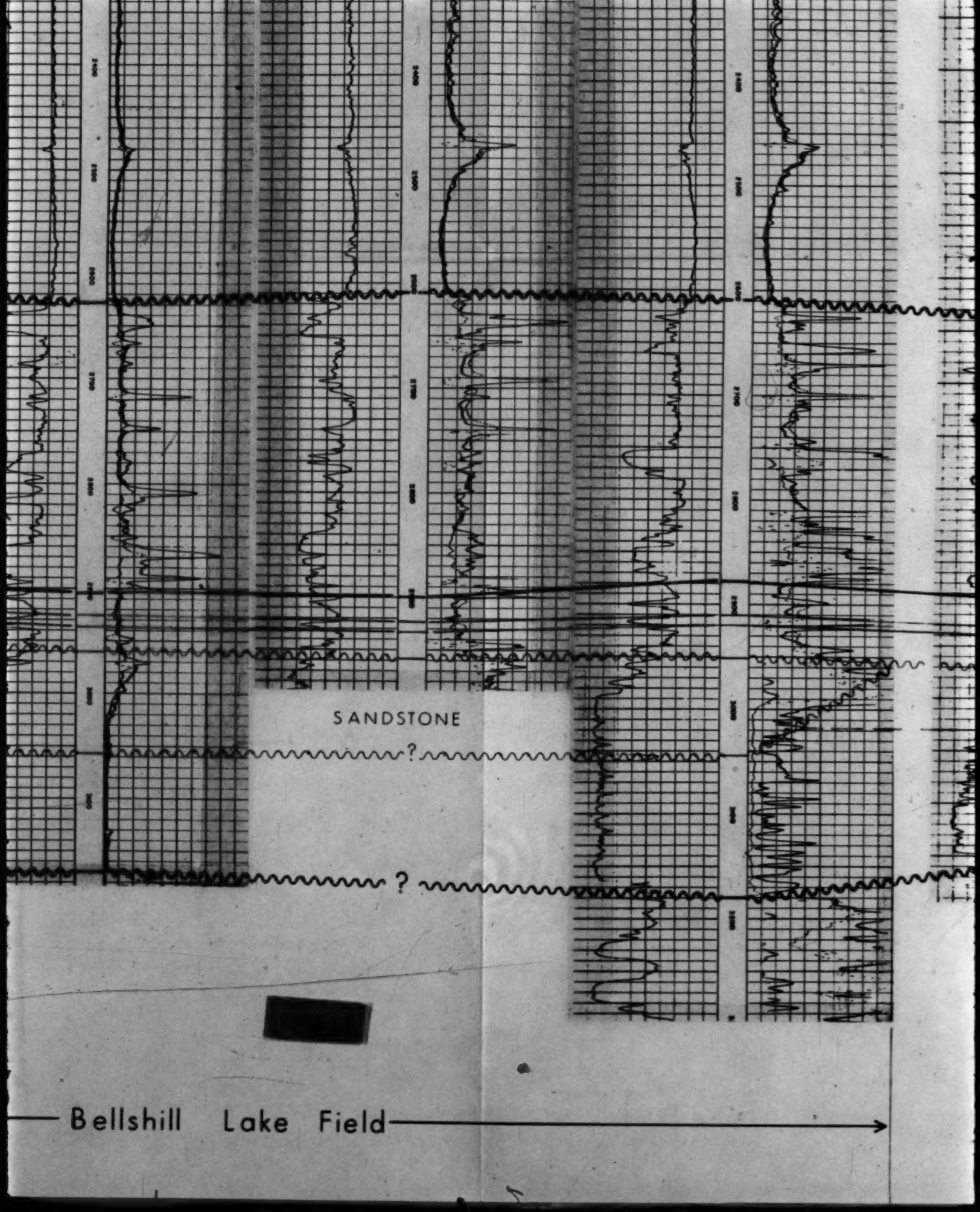
Manville Group

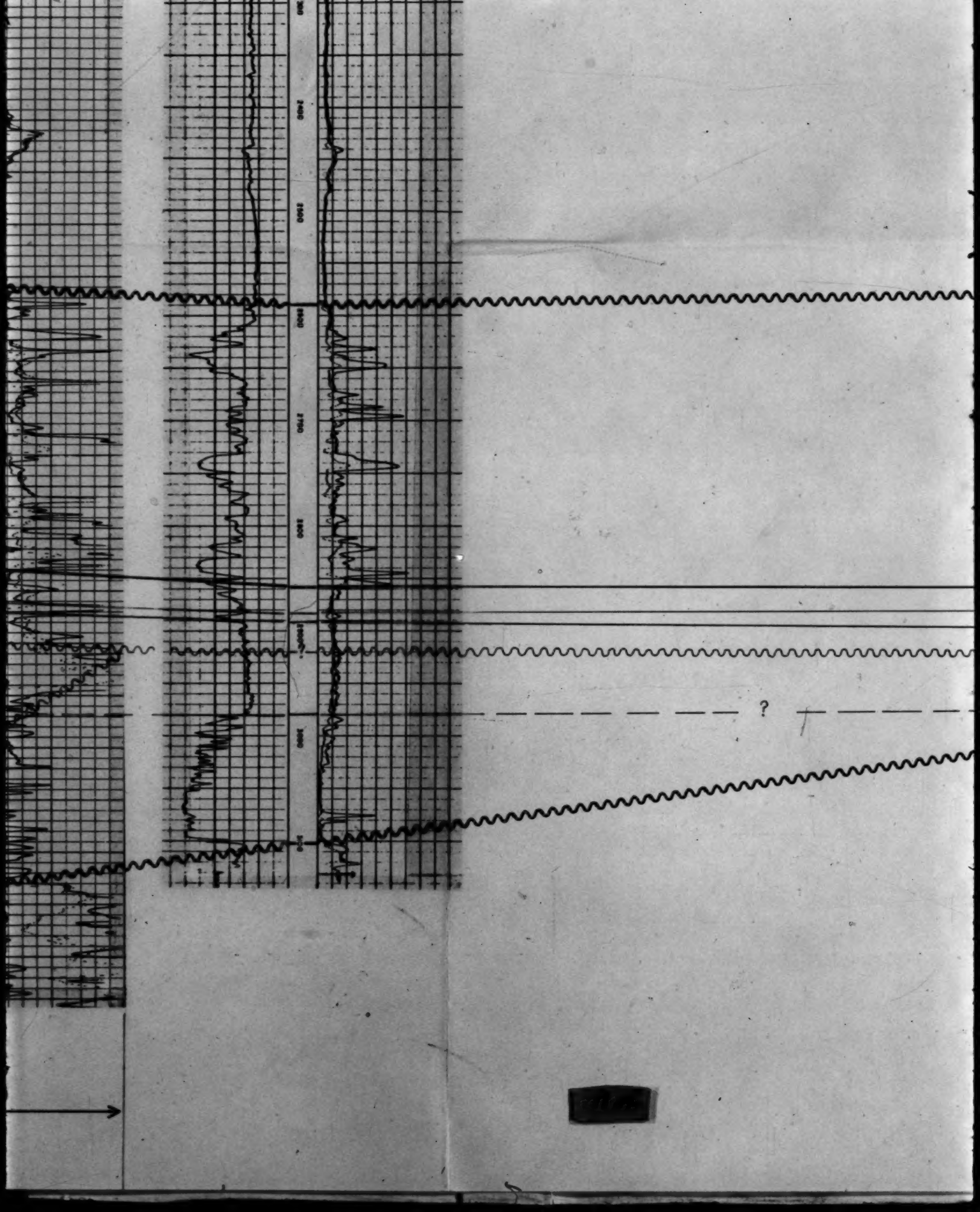
LOWER CRETACEOUS

UPPER DEVO


ELLERSLIE MB.
DEVILLE MB. ?


CHANNEL
?
?
Bells


SANDSTONE
?
?
Bellshill Lake Field



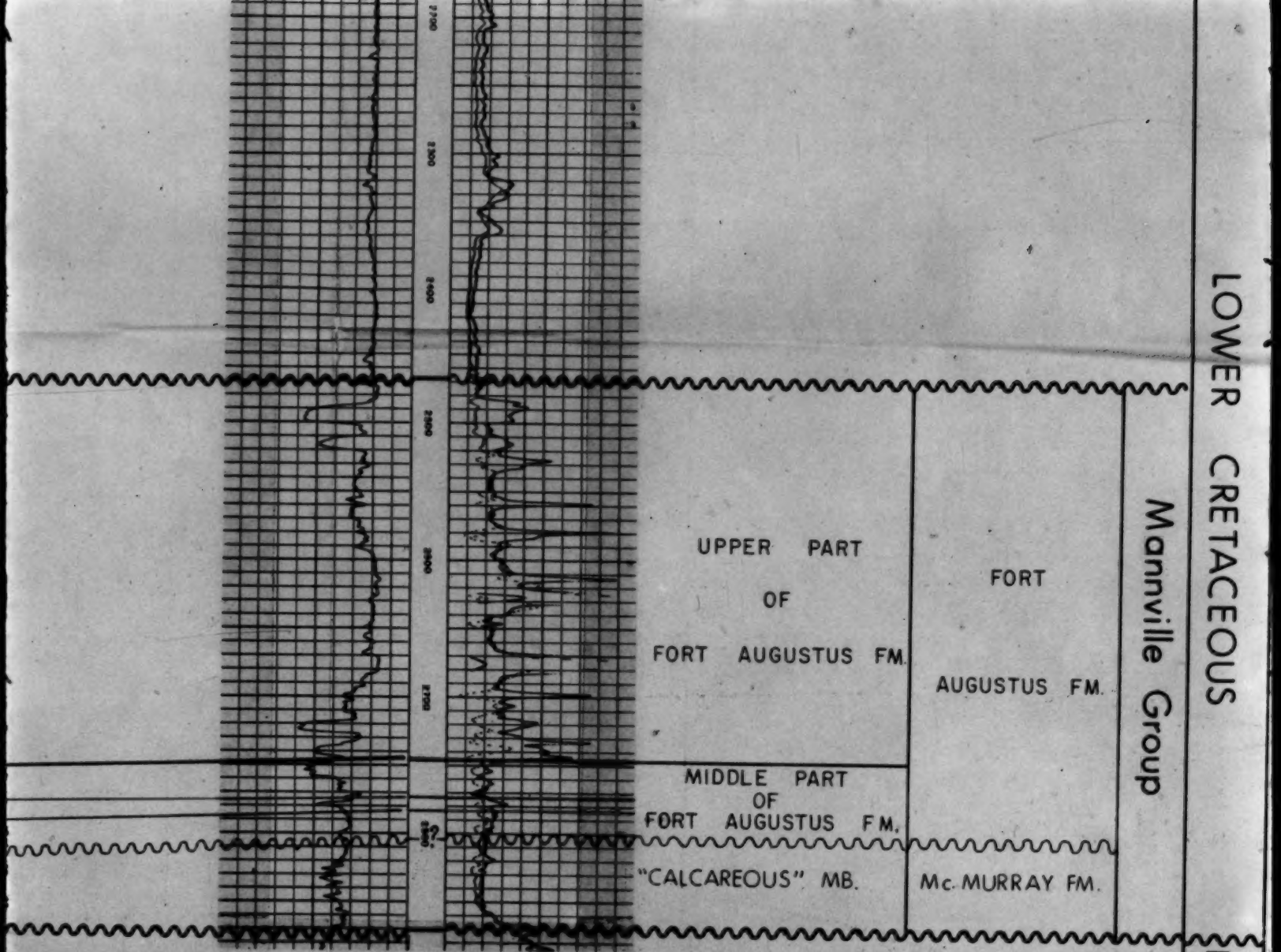


Figure 5.

STRATIGRAPHIC CROSS SECTION II.

MARWAYNE BACKMANN N°7-30 to NEW GAS EXPLORATION PACIFIC HARDISTY N°4

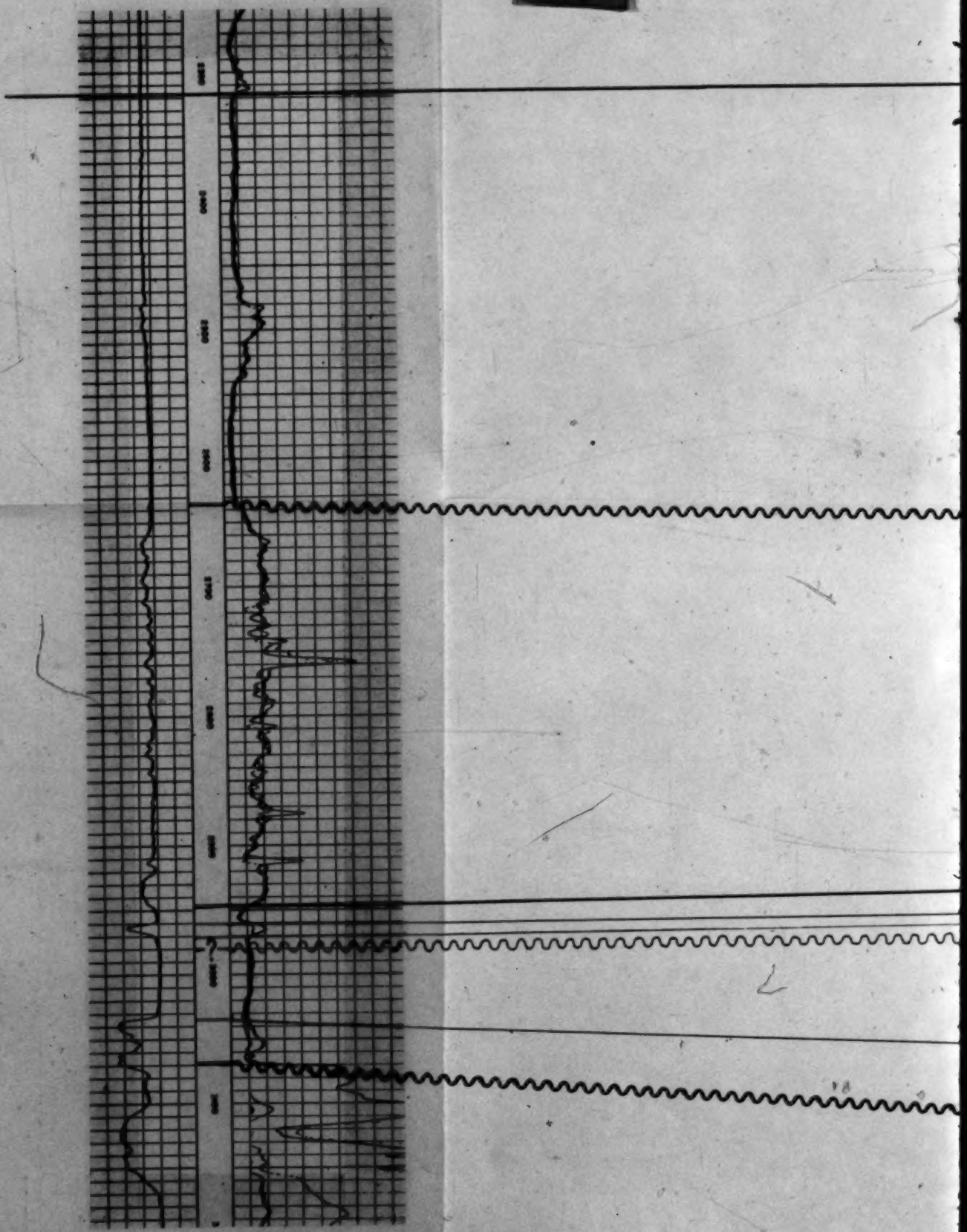
Vertical scale: 1"=100 ft., Horizontal scale: 1"=0·5 mi.
(exept when the distance between two wells is less than 1·57 mile.)

G.L. Cartier, 1976

7-36-39-13W4

K.B. 2151

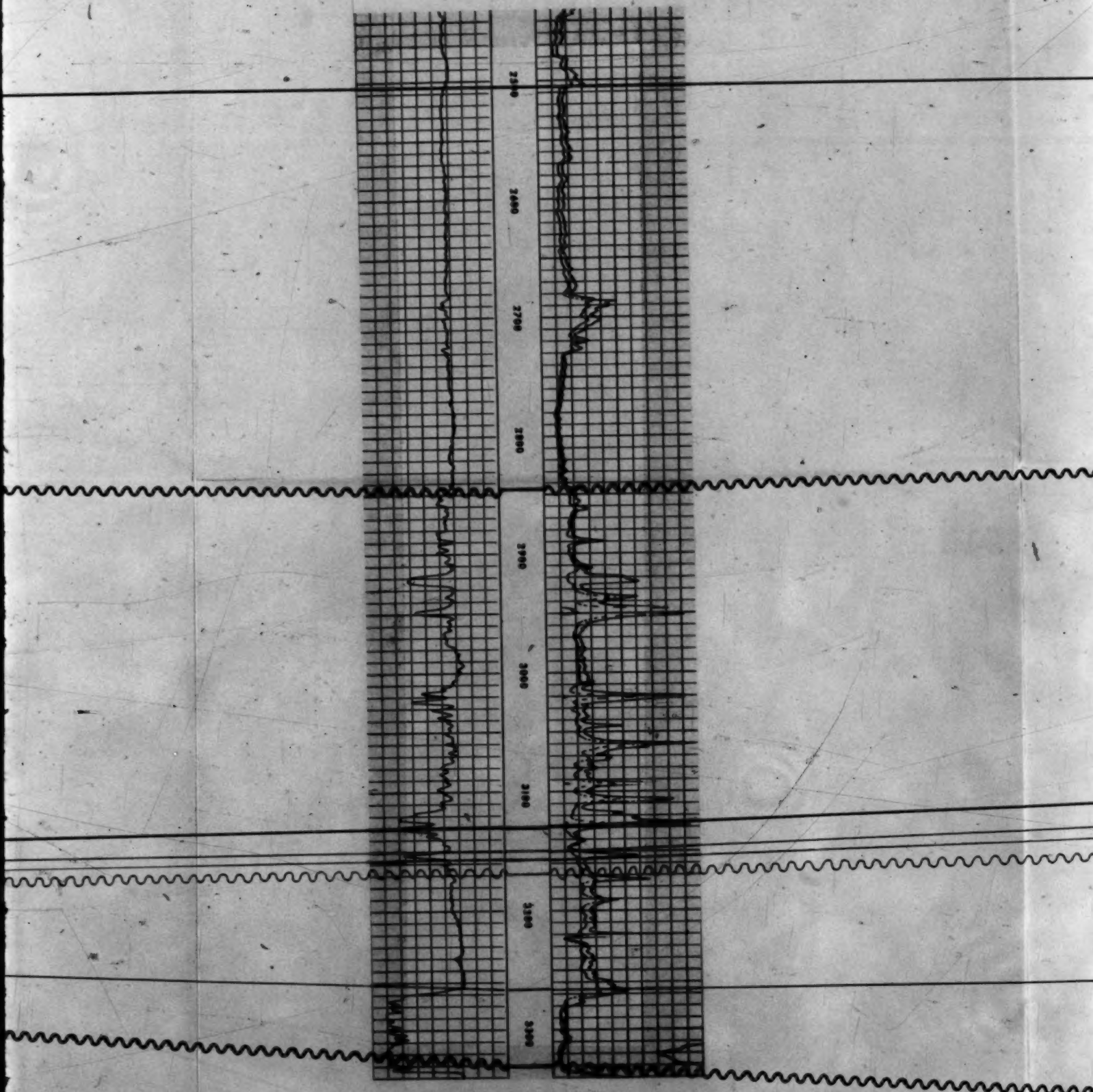
C



13-2-40-12W4

K.B. 2396

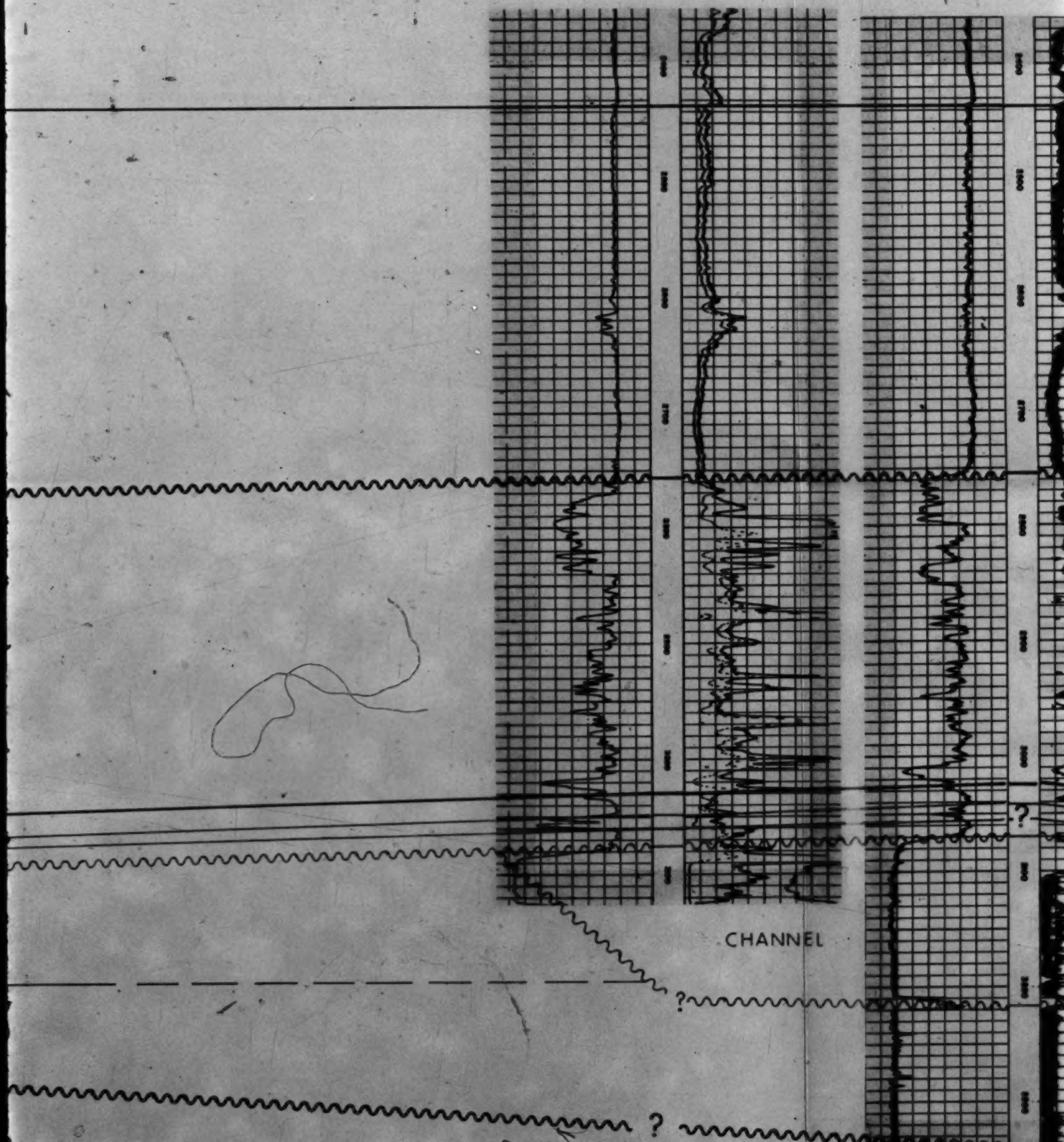
2 of



3 of

11-29-40-11W4
K.B. 2432

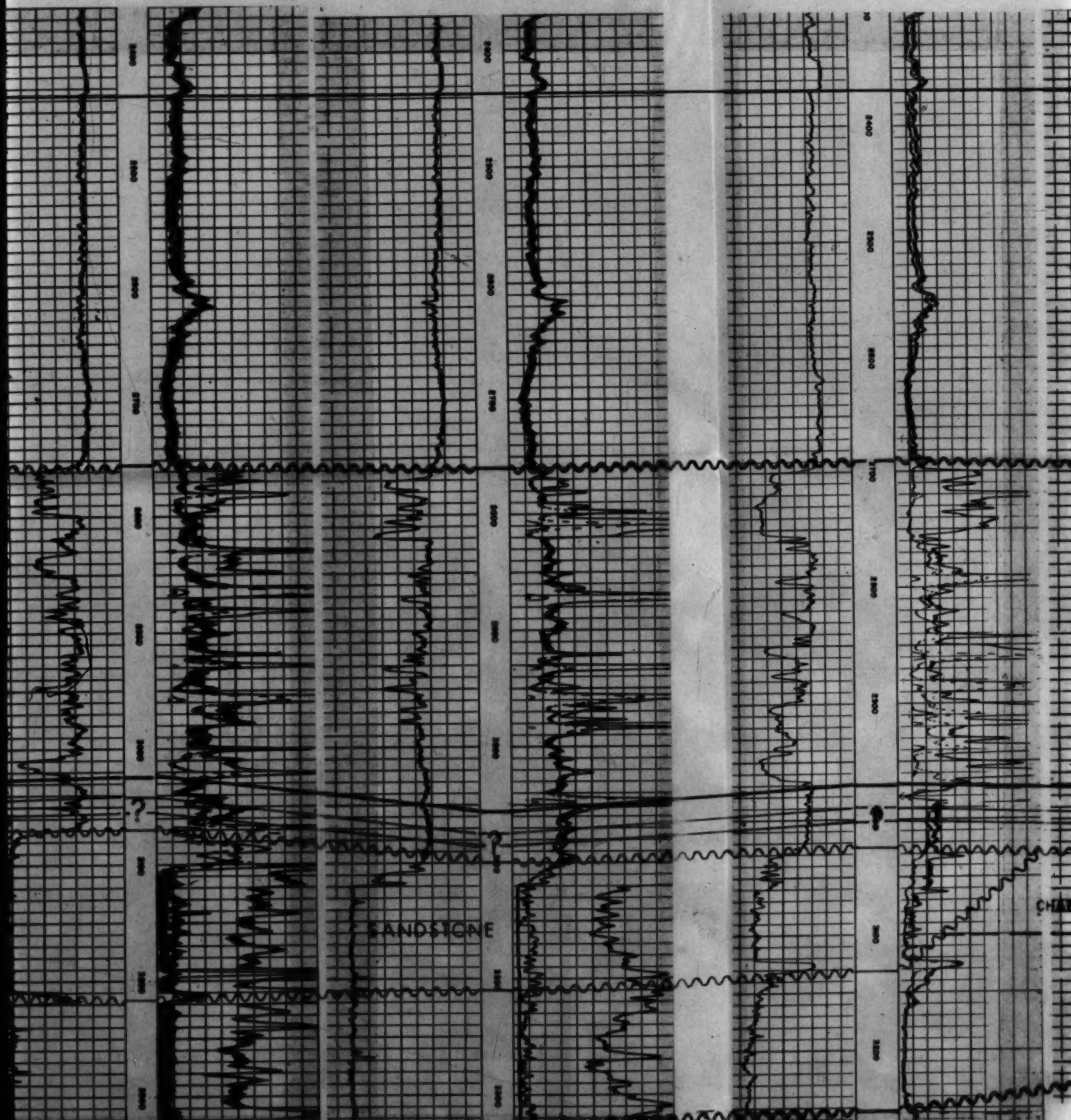
16-29-40-
K.B. 244



16-29-40-11W4
K.B. 2447

12-28-40-11W4
K.B. 2443

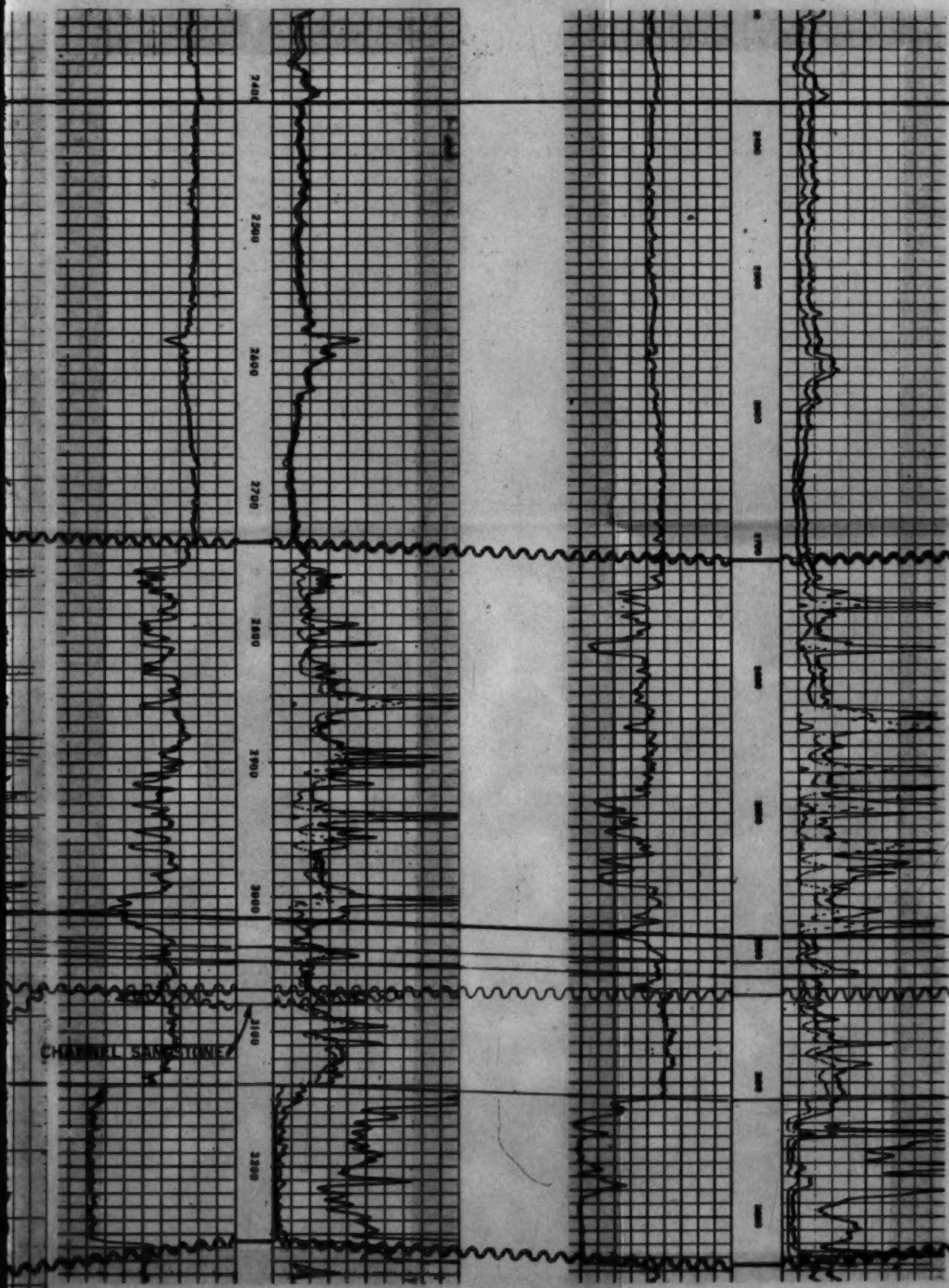
11-34-40-11W4
K.B. 2401



16-3-41-11W4
K.B. 2439

11-14-41-11W4
K.B. 2424

5 of

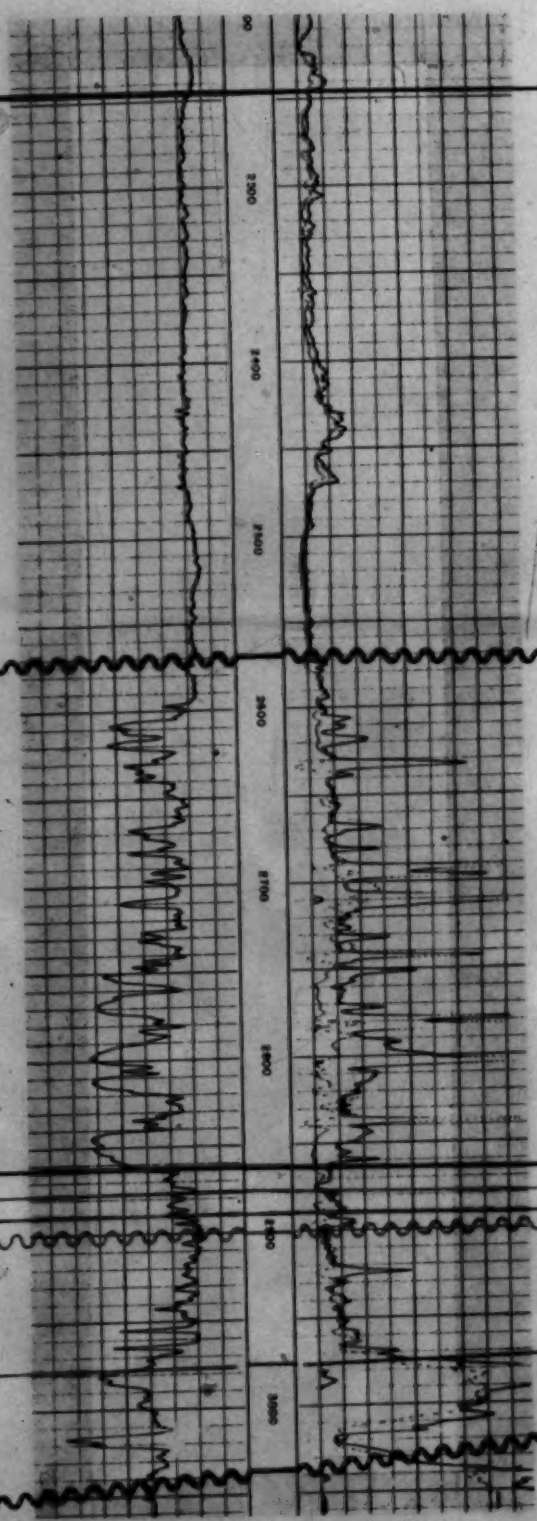


"CAL

ELLE
DEV

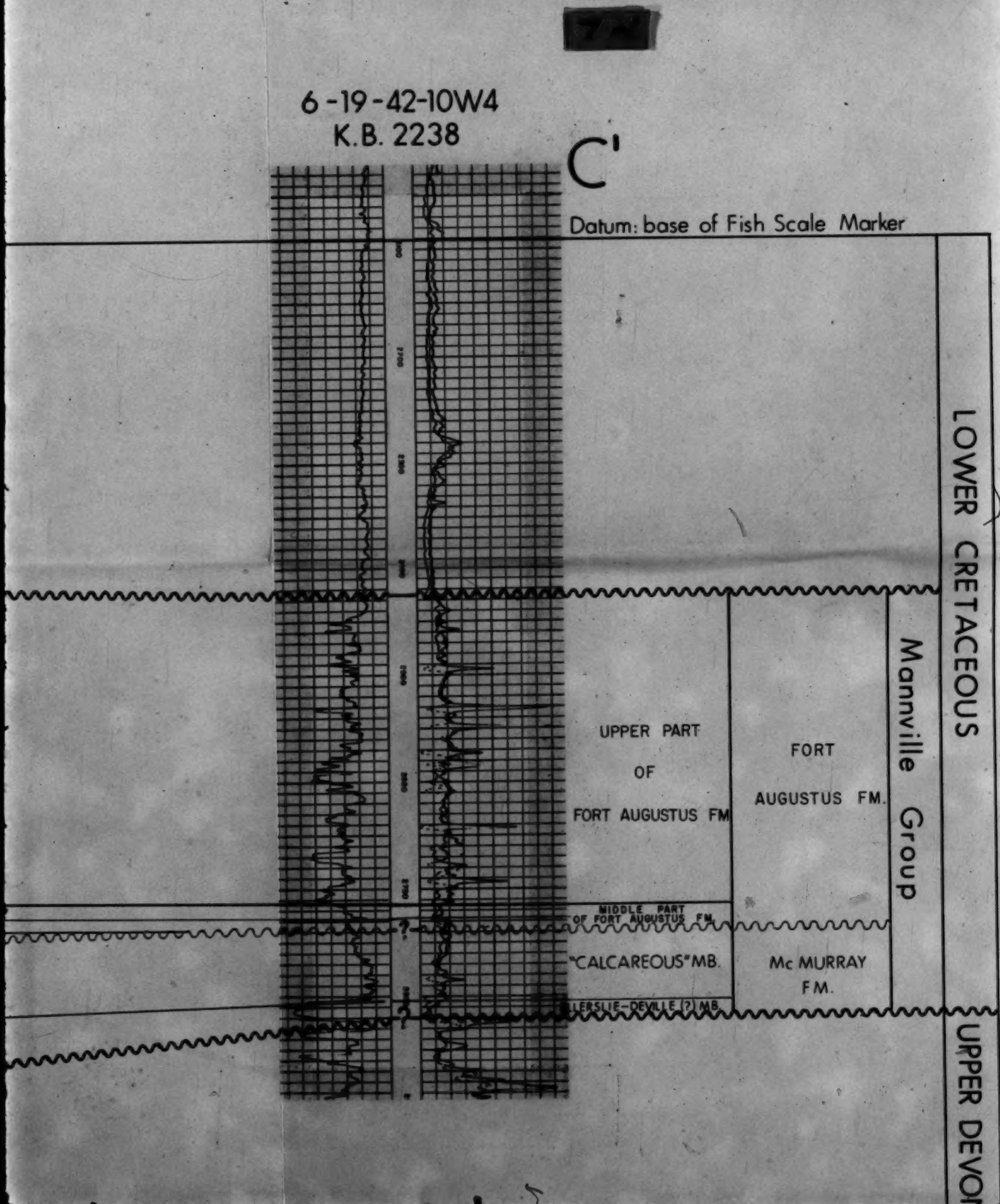
[redacted]

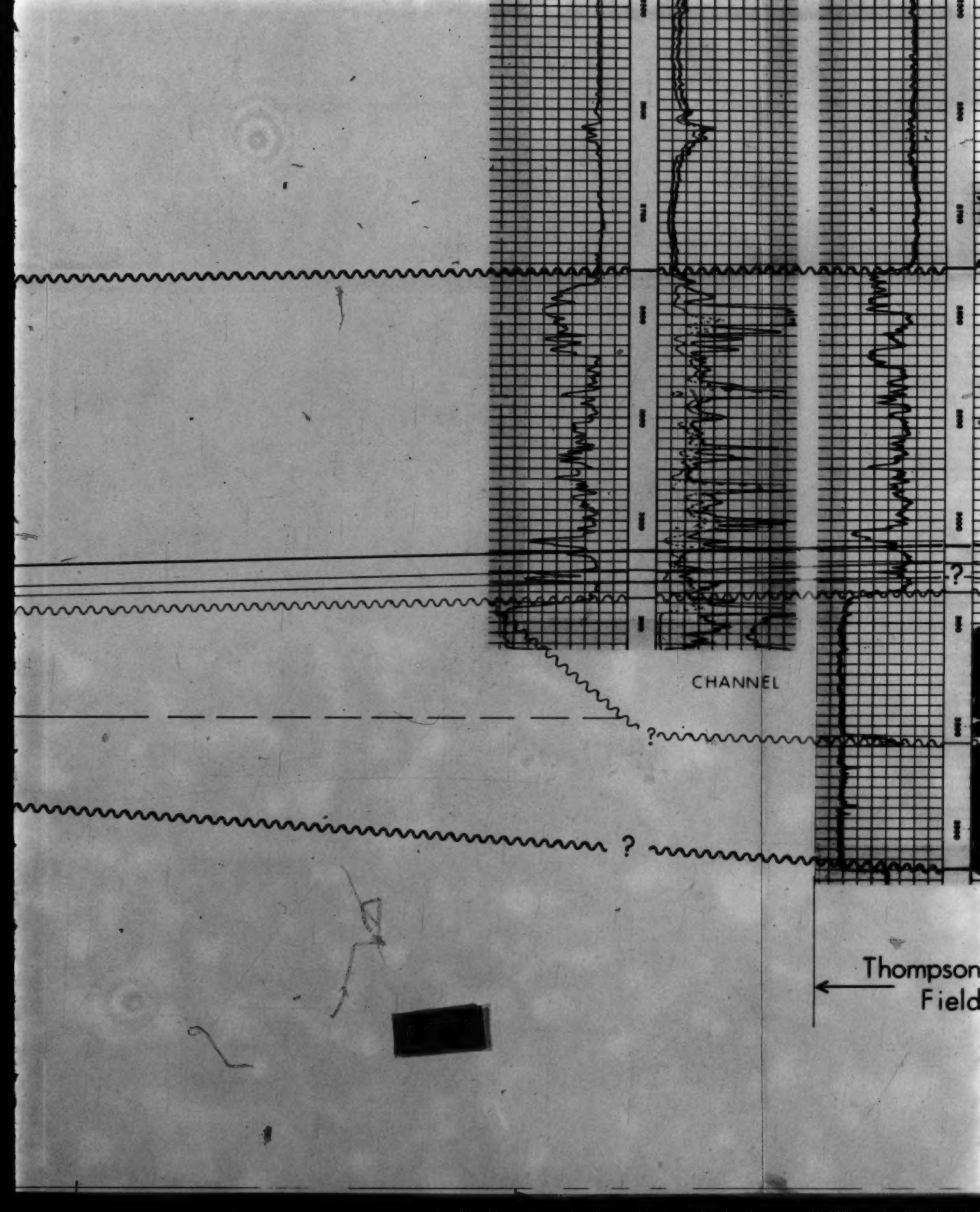
7 - 1 -42-11W4
K. B. 2328

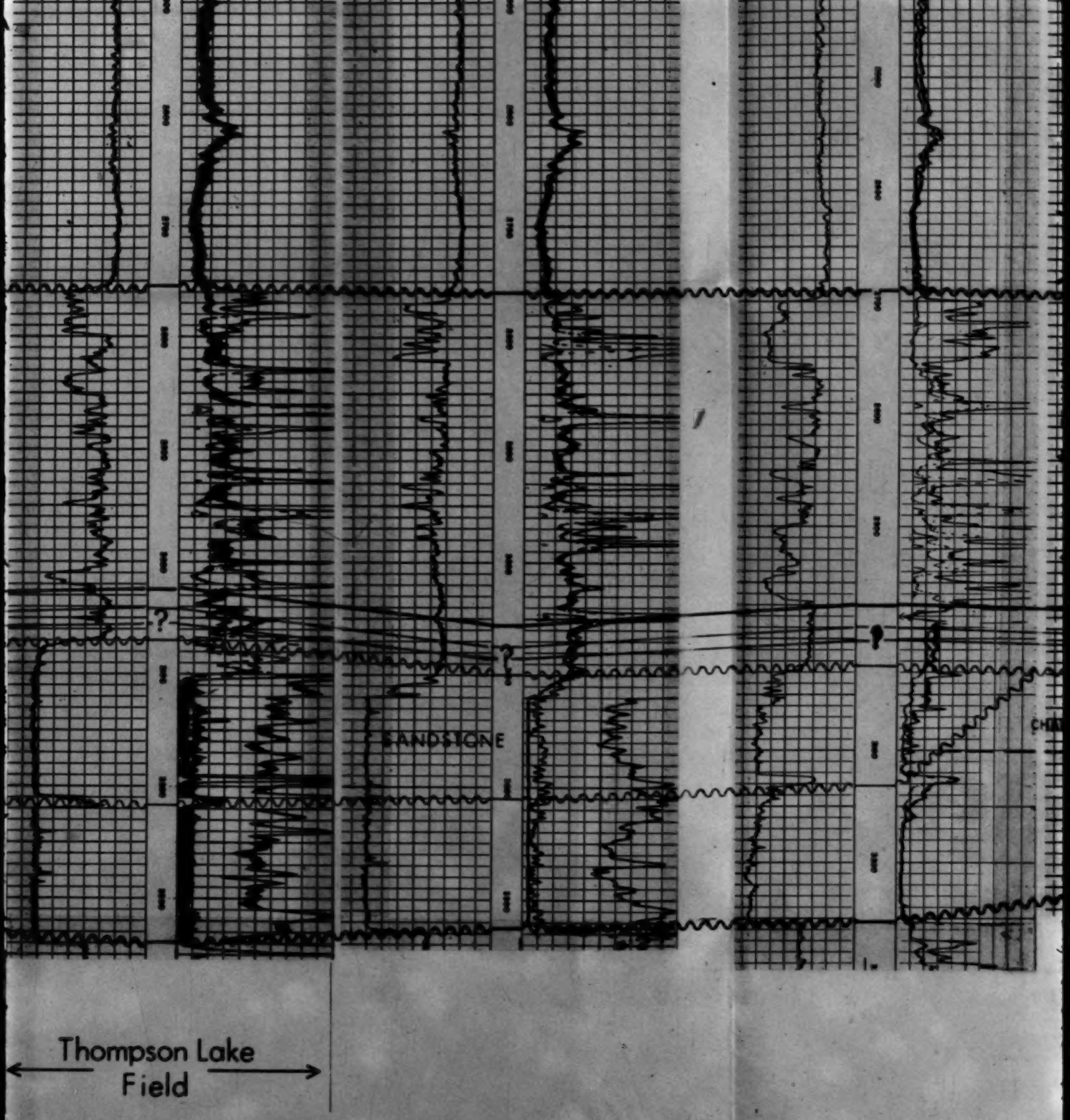


"CALCAREOUS" MB.

ELLERSLIE MB.
DEVILLE MB ?


6-19-42-10W4
K.B. 2238
C'
Datum: base of Fish Scale Marker
LOWER CRETACEOUS
Mannville Group
UPPER PART
OF
FORT AUGUSTUS FM
FORT
AUGUSTUS FM.
MIDDLE PART
OF FORT AUGUSTUS FM.
"CALCAREOUS" MB.
Mc MURRAY
FM.
ERSLIE-DEVILLE (?) MB.
UPPER DEVO


?
CHANNEL
?
?
Thompson
Field


?
?
?
SANDSTONE
CHE
Thompson Lake
Field

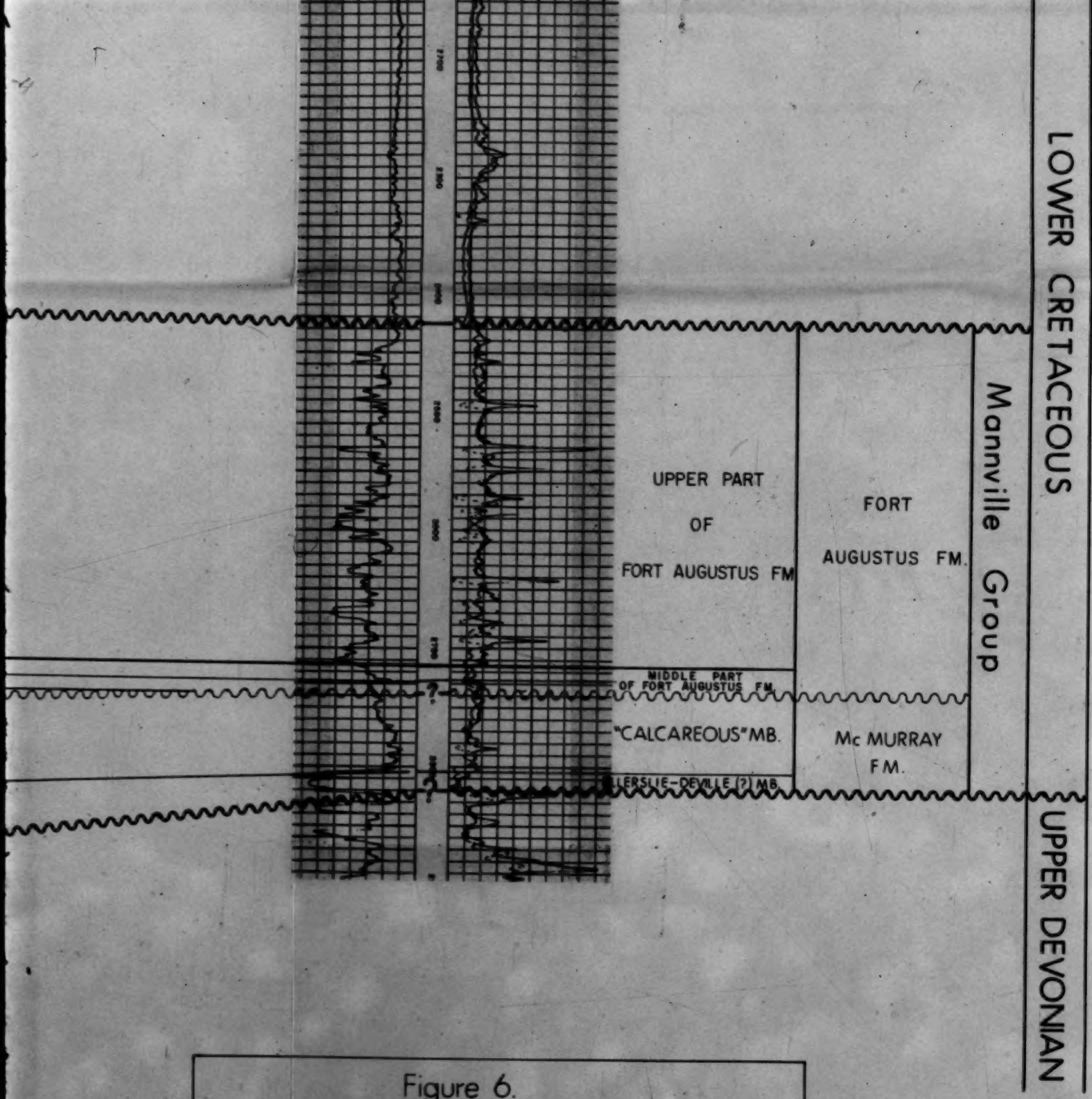


Figure 6.

STRATIGRAPHIC CROSS SECTION III.

MARWAYNE HEFFEL N°7-36 to GRASS LAKE N°6-19

Vertical scale: 1" =100ft, Horizontal scale: 1"=0.5mi.
(exept when the distance between two wells is less than 1.57 mile.)

G.L.Cartier, 1976

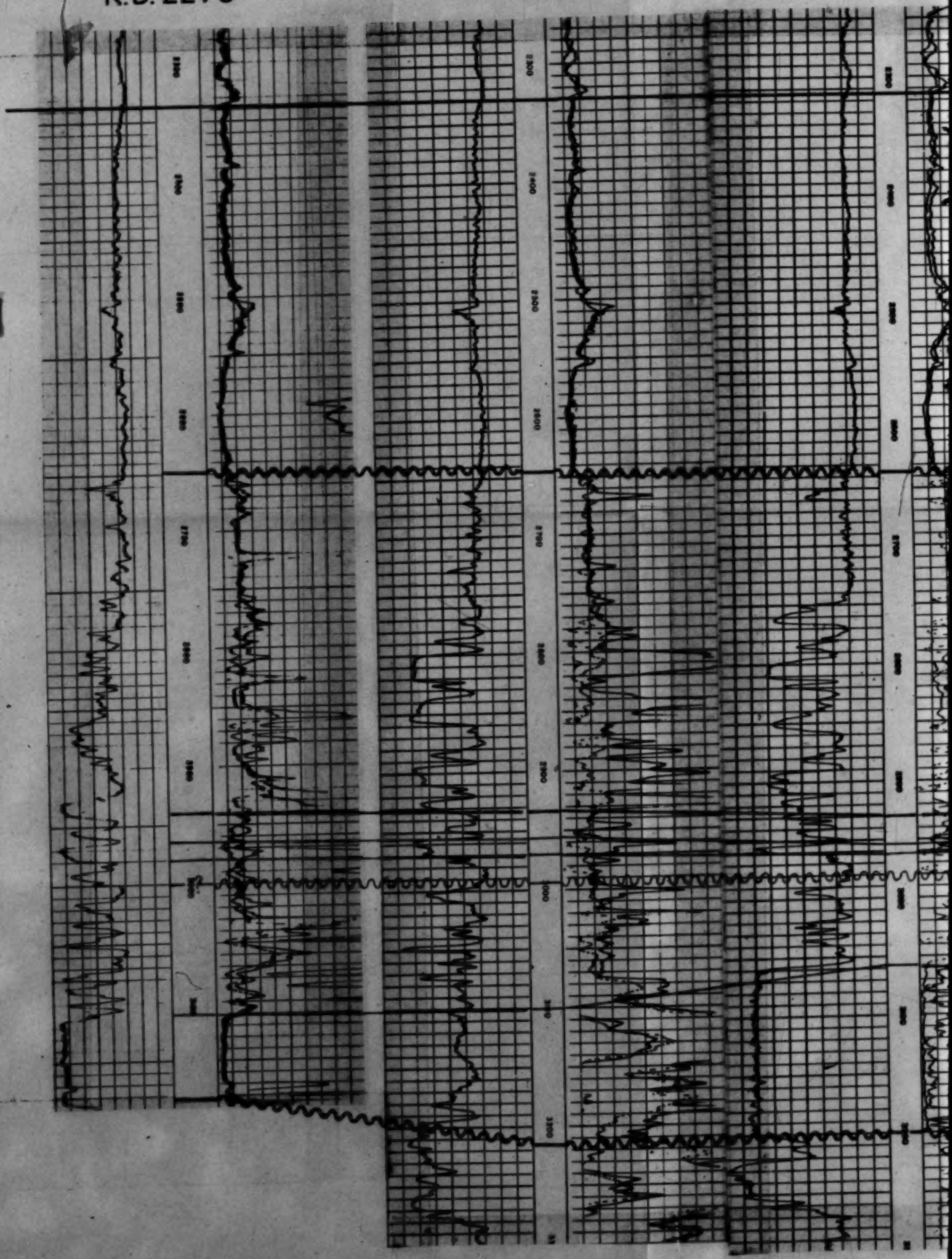
110410

D

10-4-43-13W4
K.B. 2293

6-34-42-13W4
K.B.2327

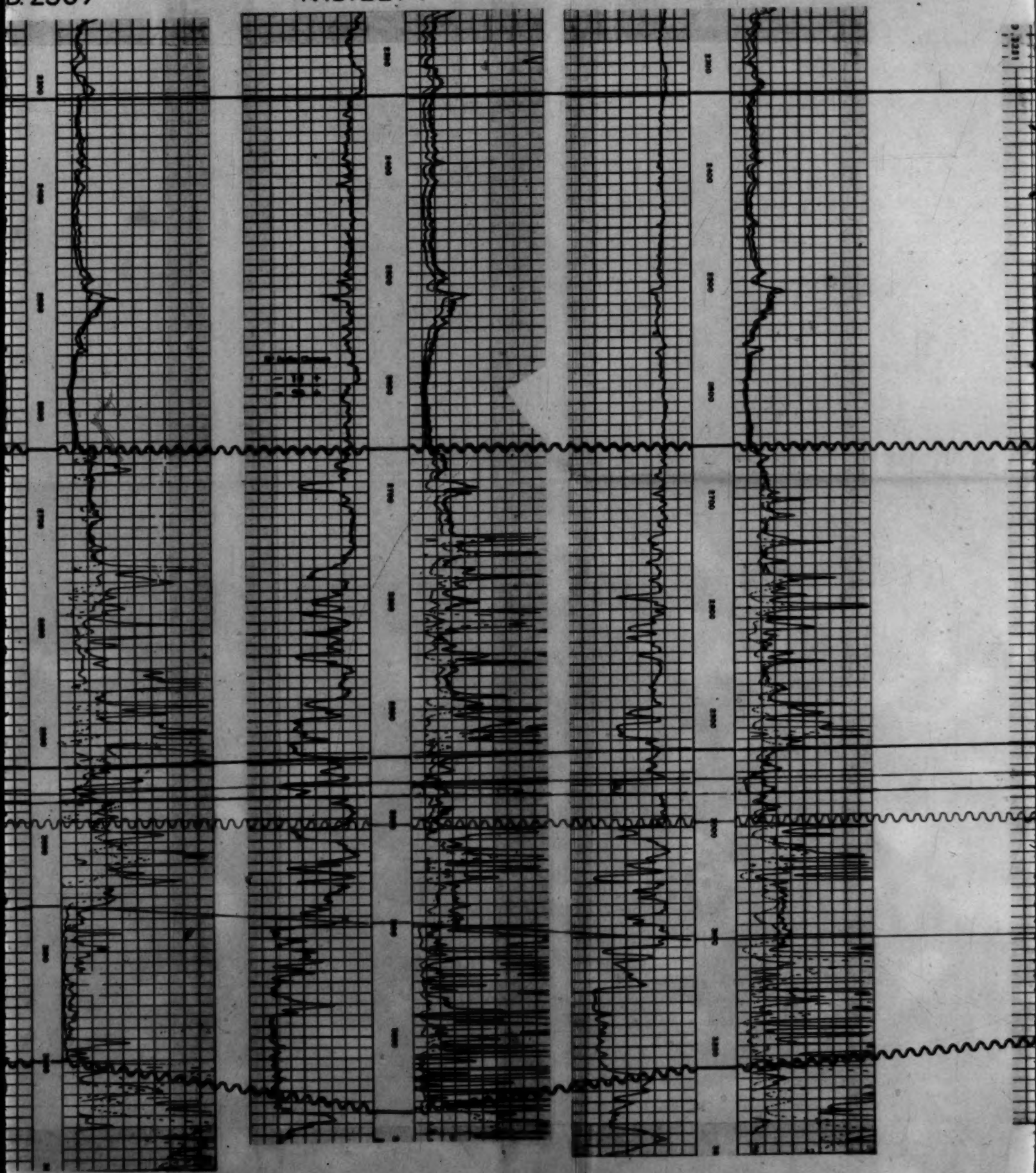
10-27-42-13
K.B. 2309



-42-13W4
B. 2309

4-23-42-13W4
K.B. 2294

12-23-42-13W4
K.B. 2289

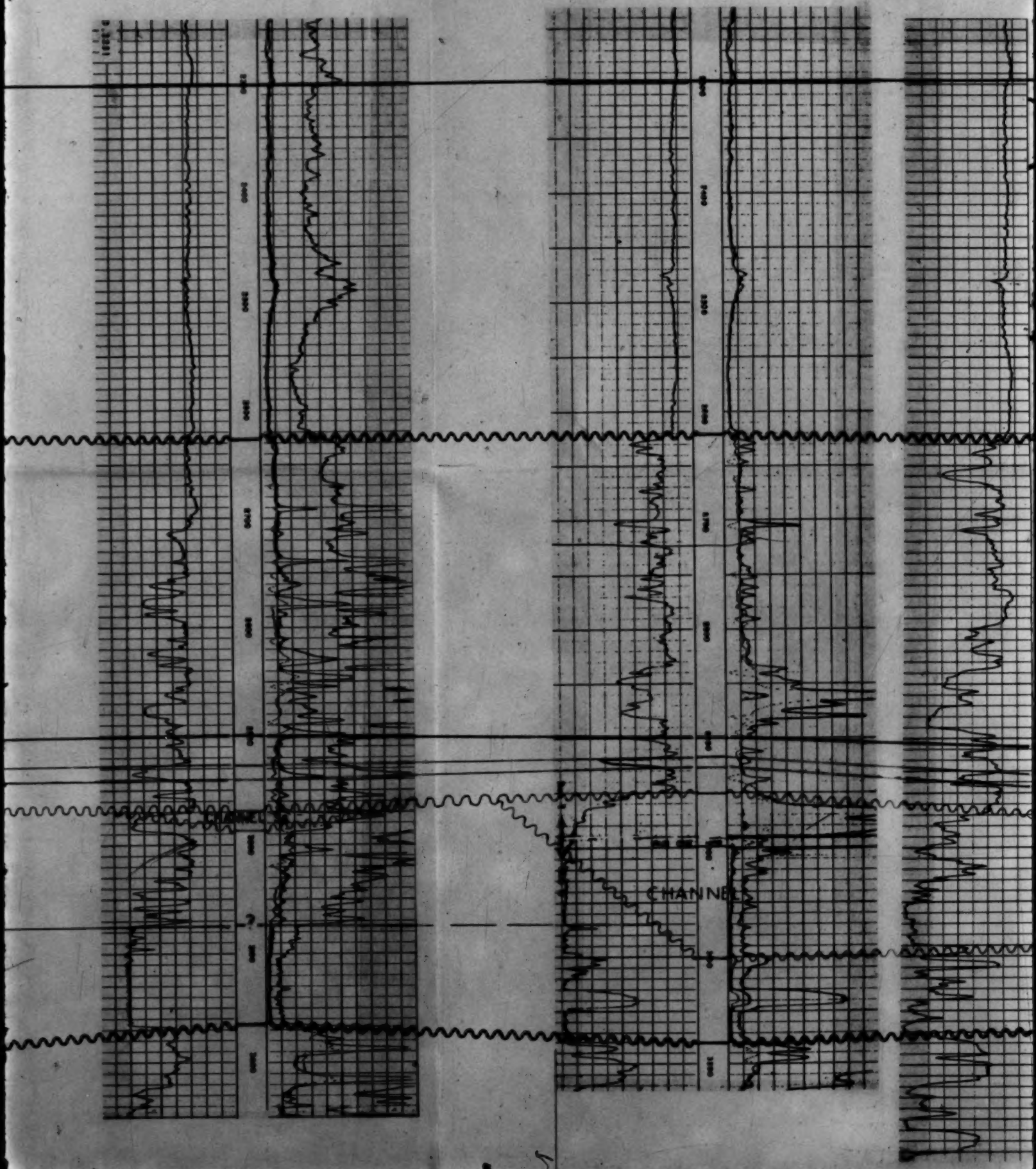


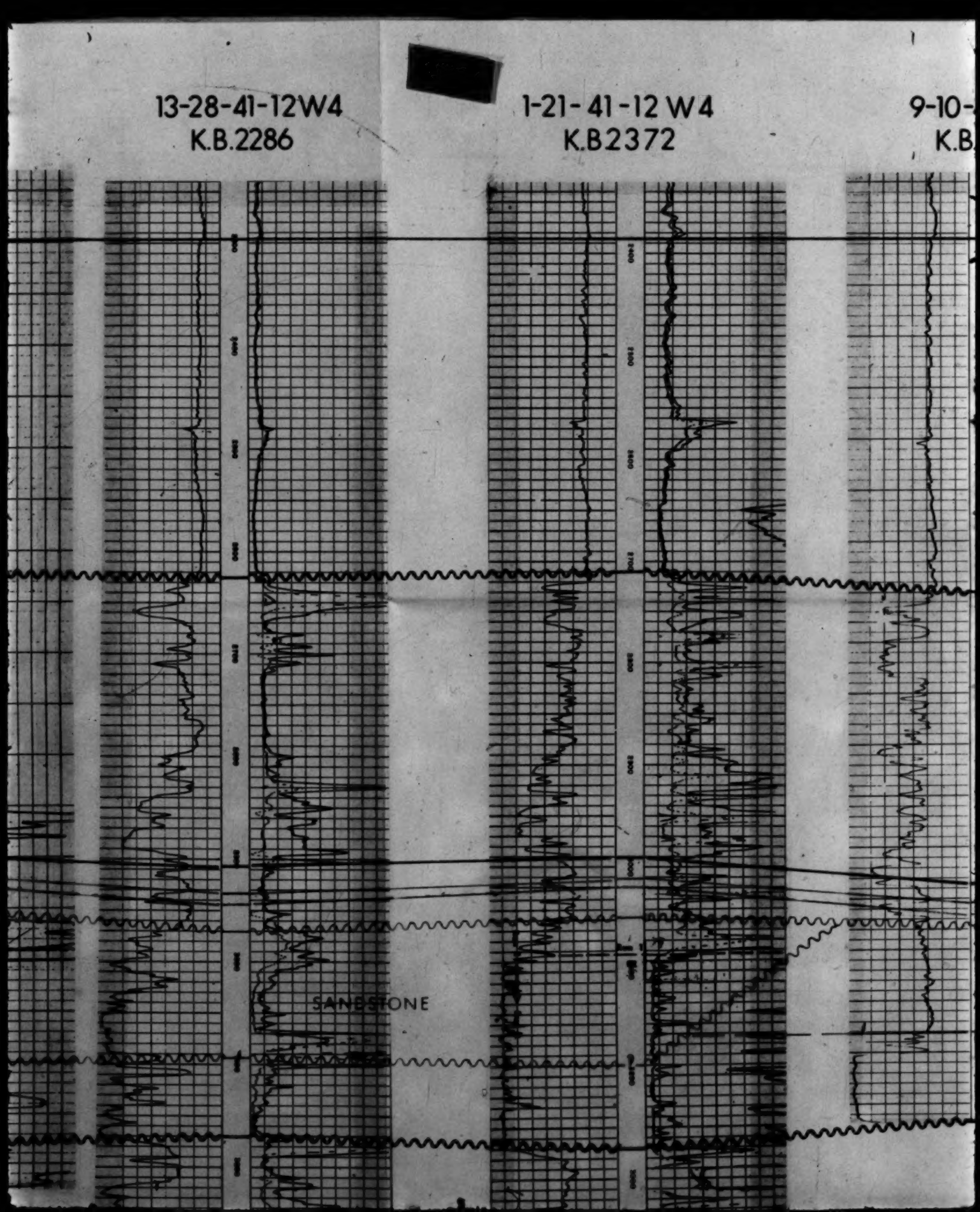
7- 7-42-12W4
K.B. 2261

3 of

6-32-41-12W4
K. B.2279

13-28-
K.B



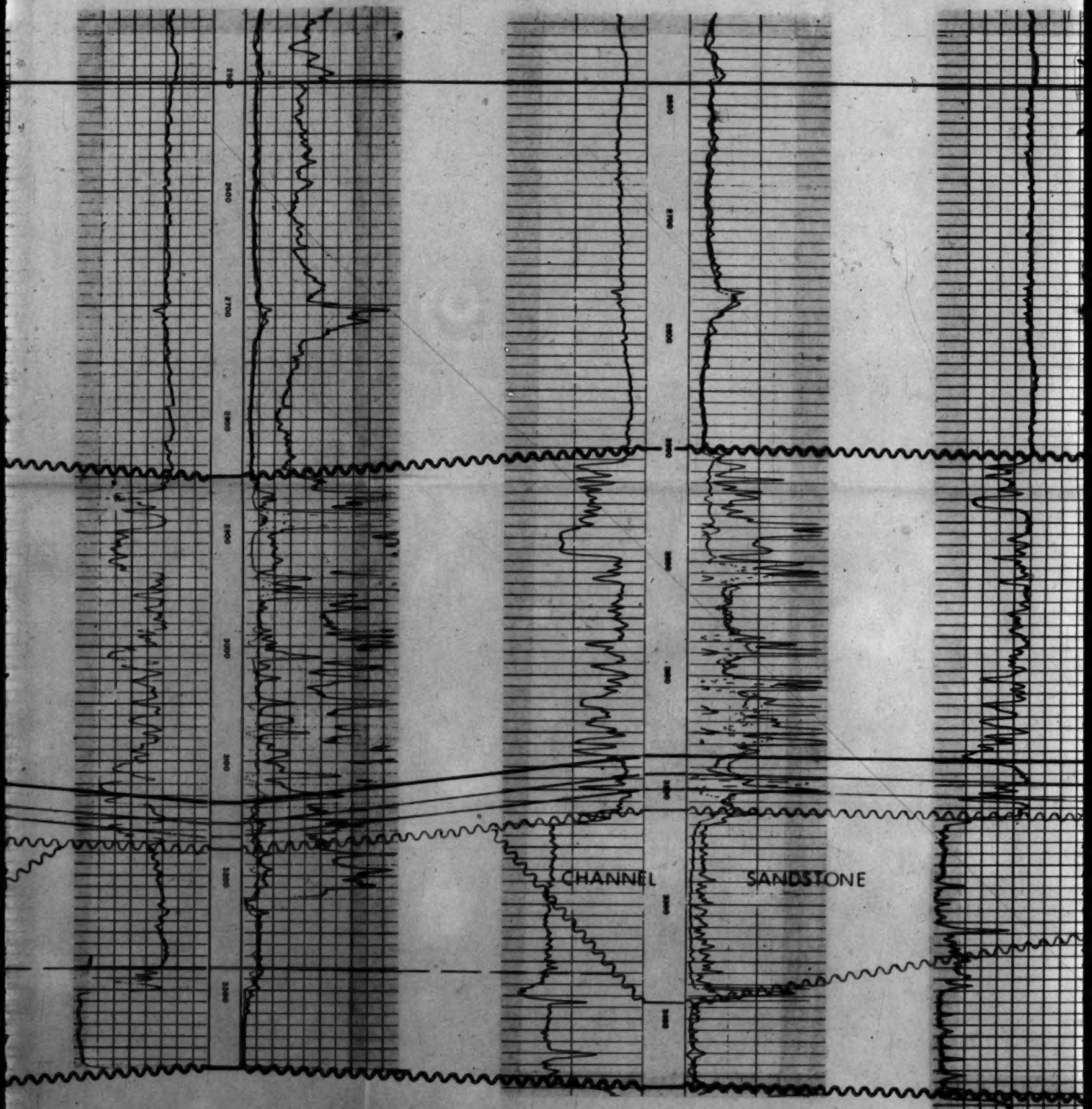

13-28-41-12W4
K.B.2286
1-21-41-12 W4
K.B2372
9-10-
K.B
SANDSTONE

54

9-10-41-12 W4
K.B. 2477

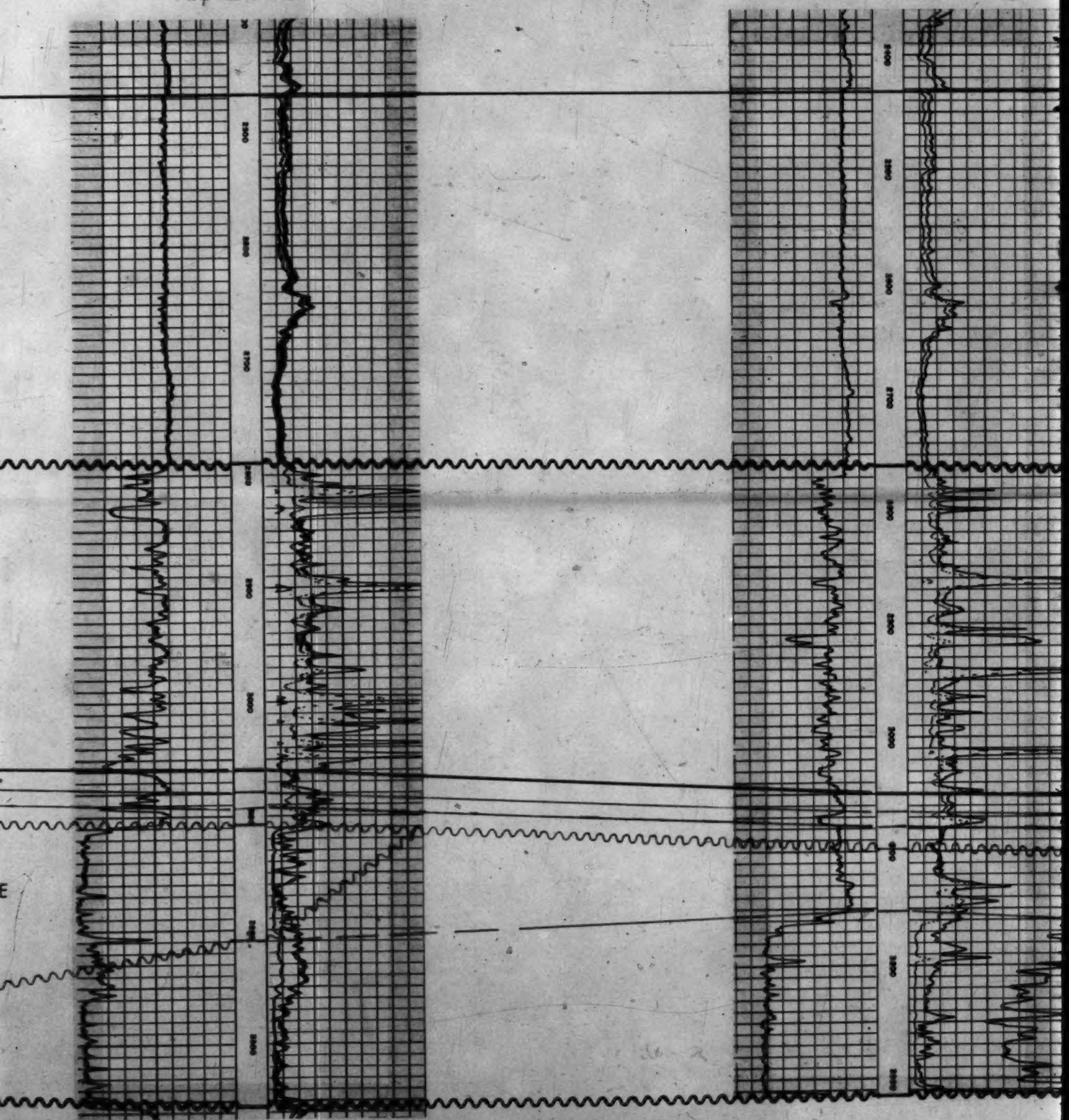
2-12-41-12 W4
K.B. 2574

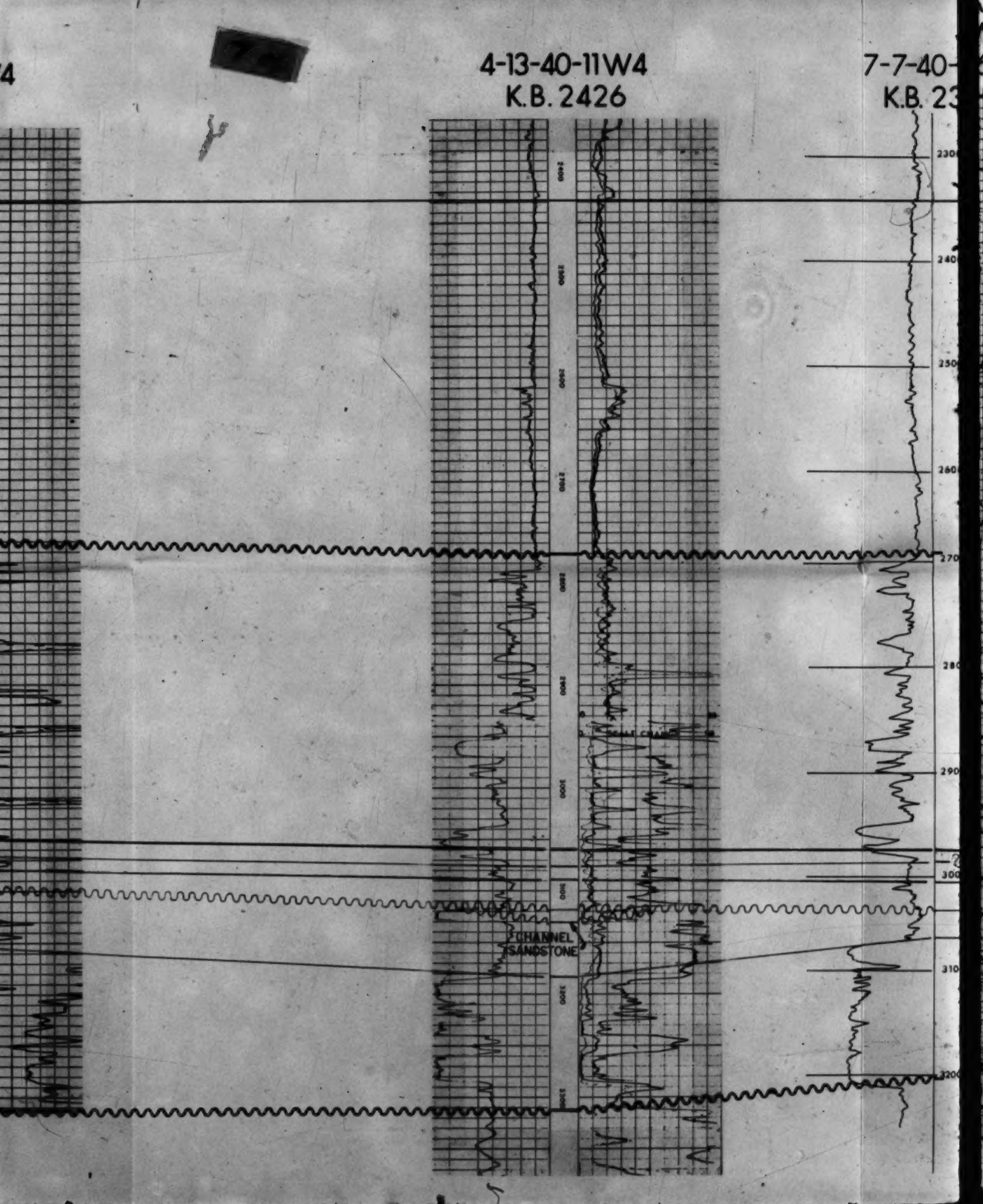
6-31-
K.B

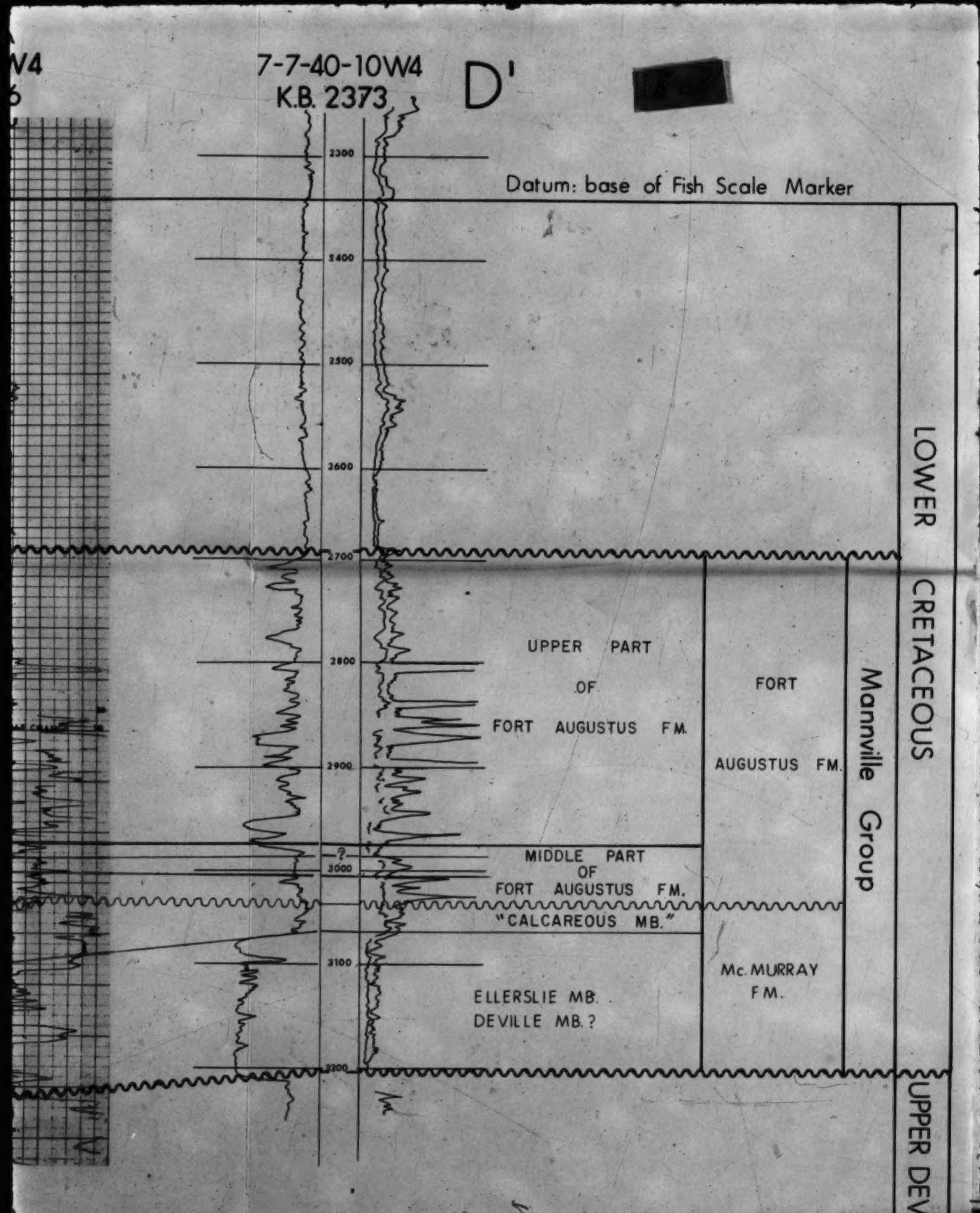


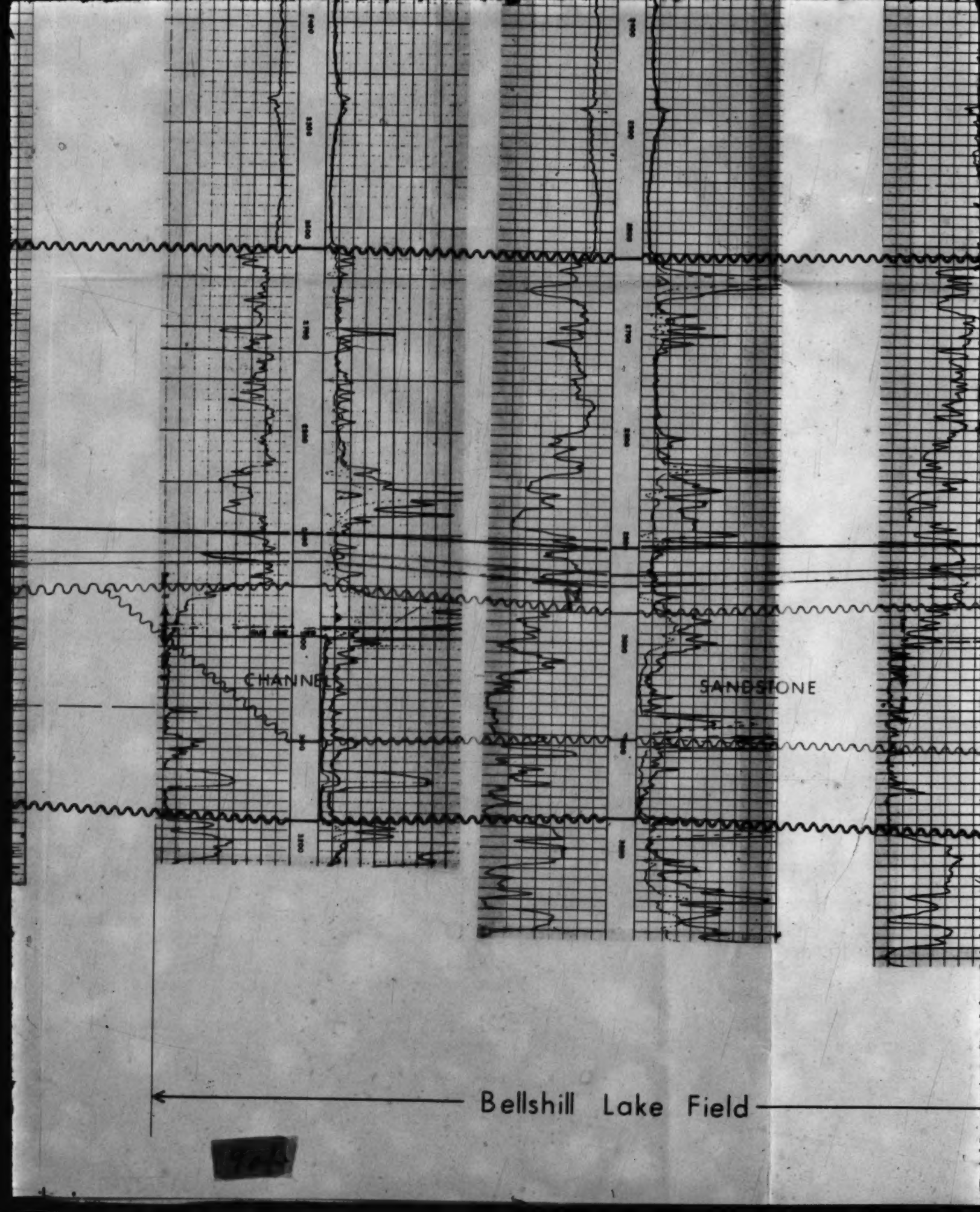
6-31-40-11W4
K.B.2448

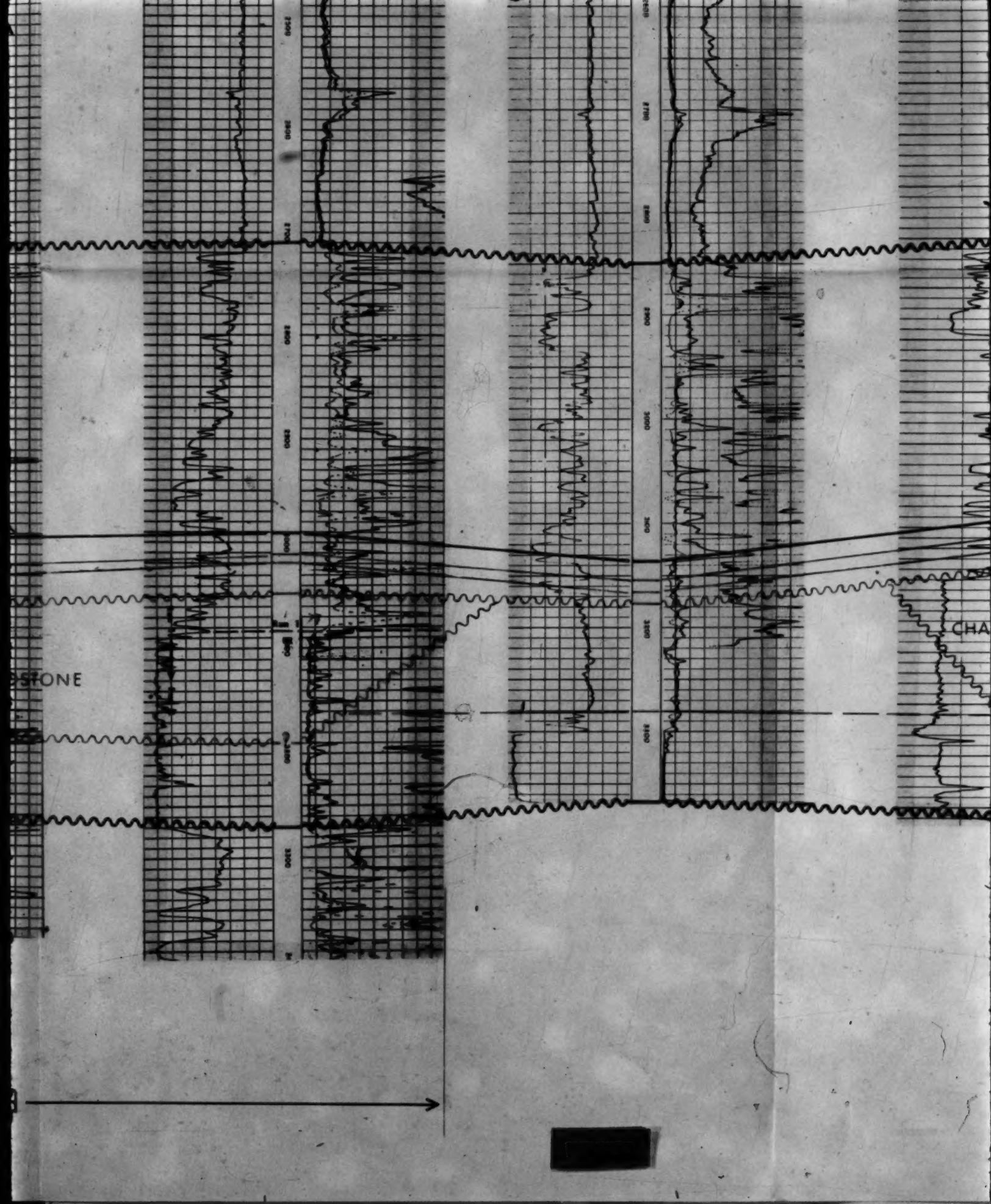
6-21-40-11W4
K.B.2418




4-13-40-11W4
K.B. 2426
7-7-40-
K.B. 23
CHANNEL SANDSTONE


7-7-40-10W4
K.B. 2373
D'
Datum: base of Fish Scale Marker
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
UPPER PART
OF
FORT AUGUSTUS FM.
MIDDLE PART
OF
FORT AUGUSTUS FM.
"CALCAREOUS MB."
ELLERSLIE MB.
DEVILLE MB.?
FORT
AUGUSTUS FM.
Mc. MURRAY
FM.
LOWER CRETACEOUS
Mannville Group
UPPER DEV


CHANNEL
SANDSTONE
Bellshill Lake Field


STONE
CHA

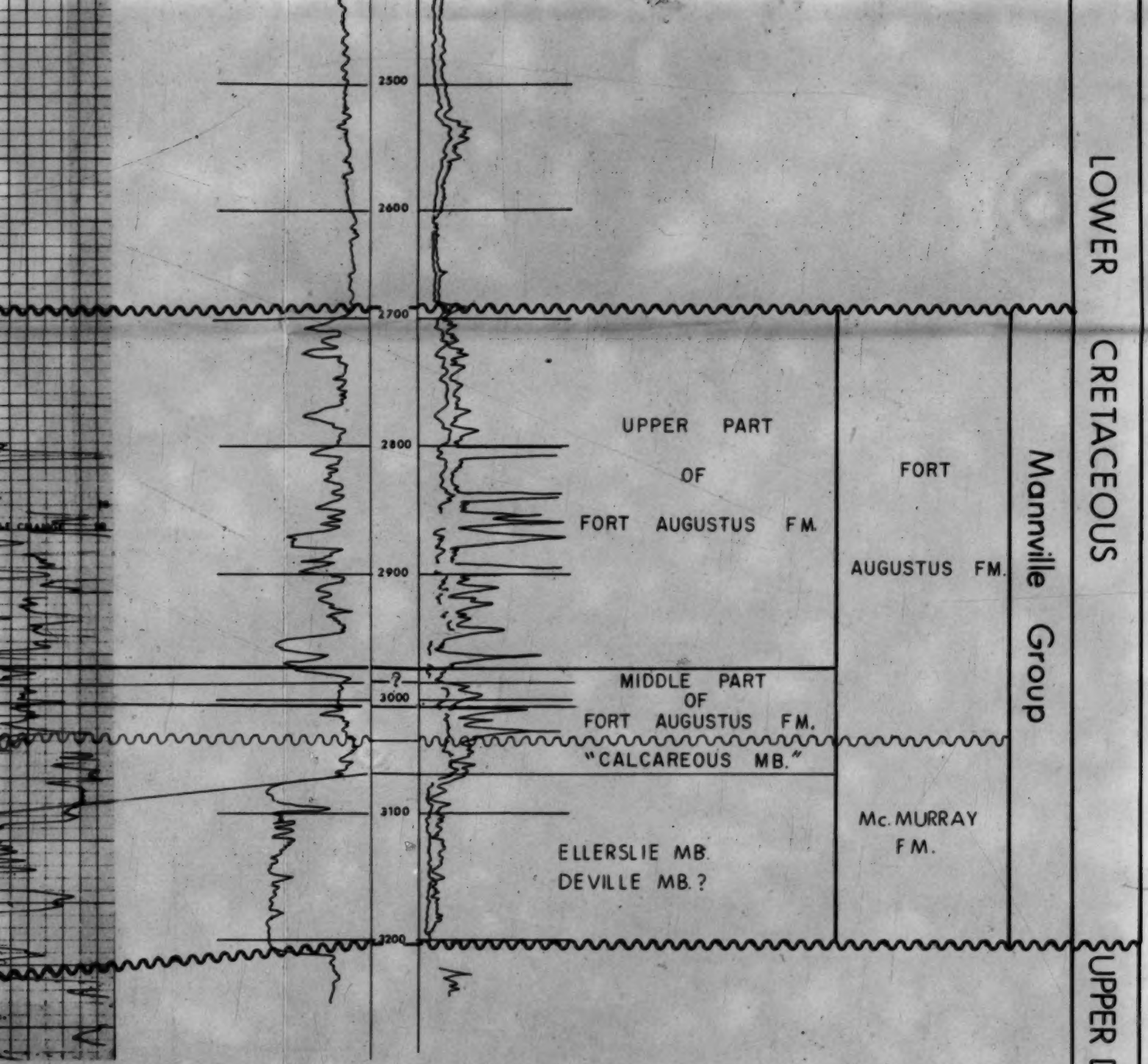


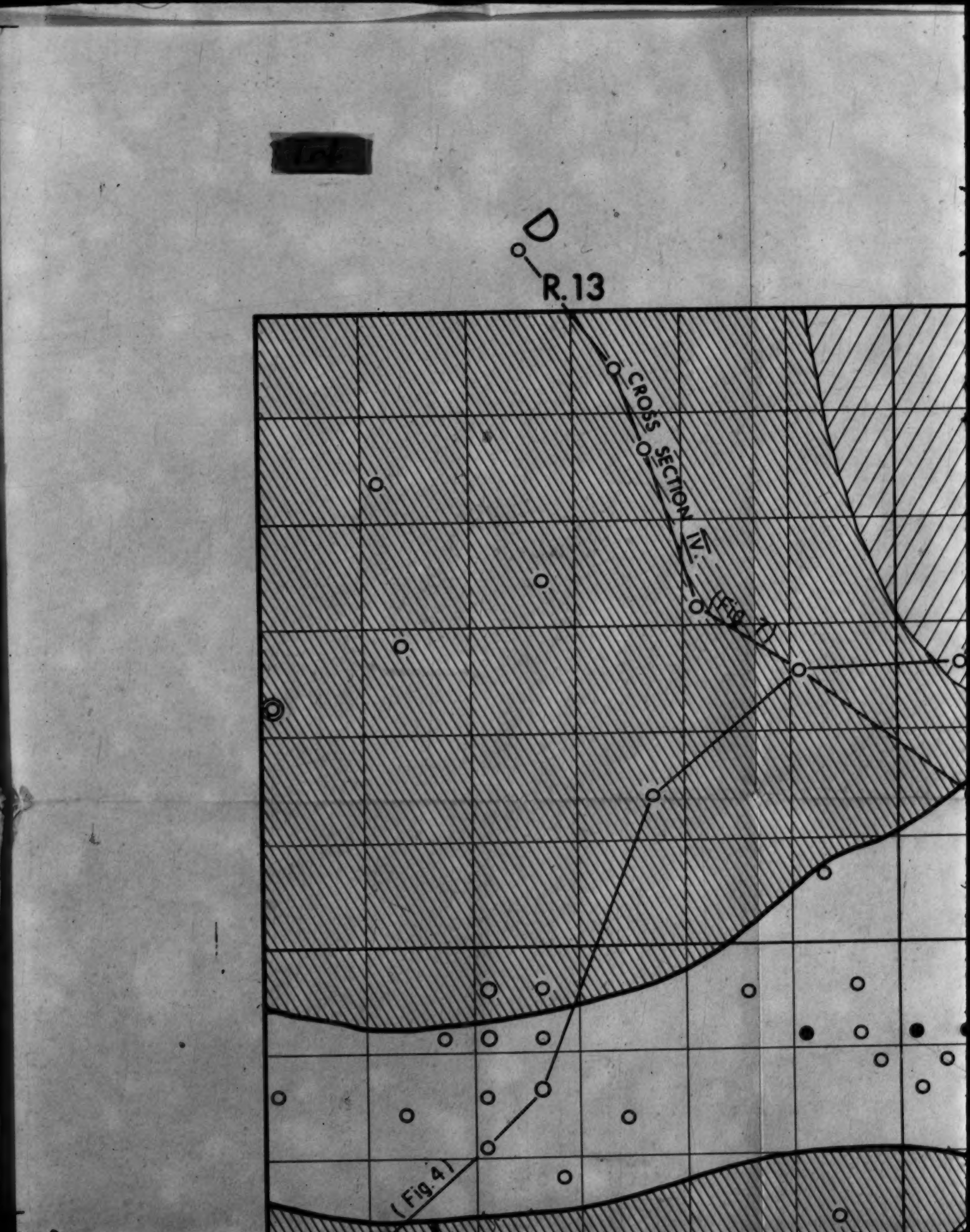
Figure 7.

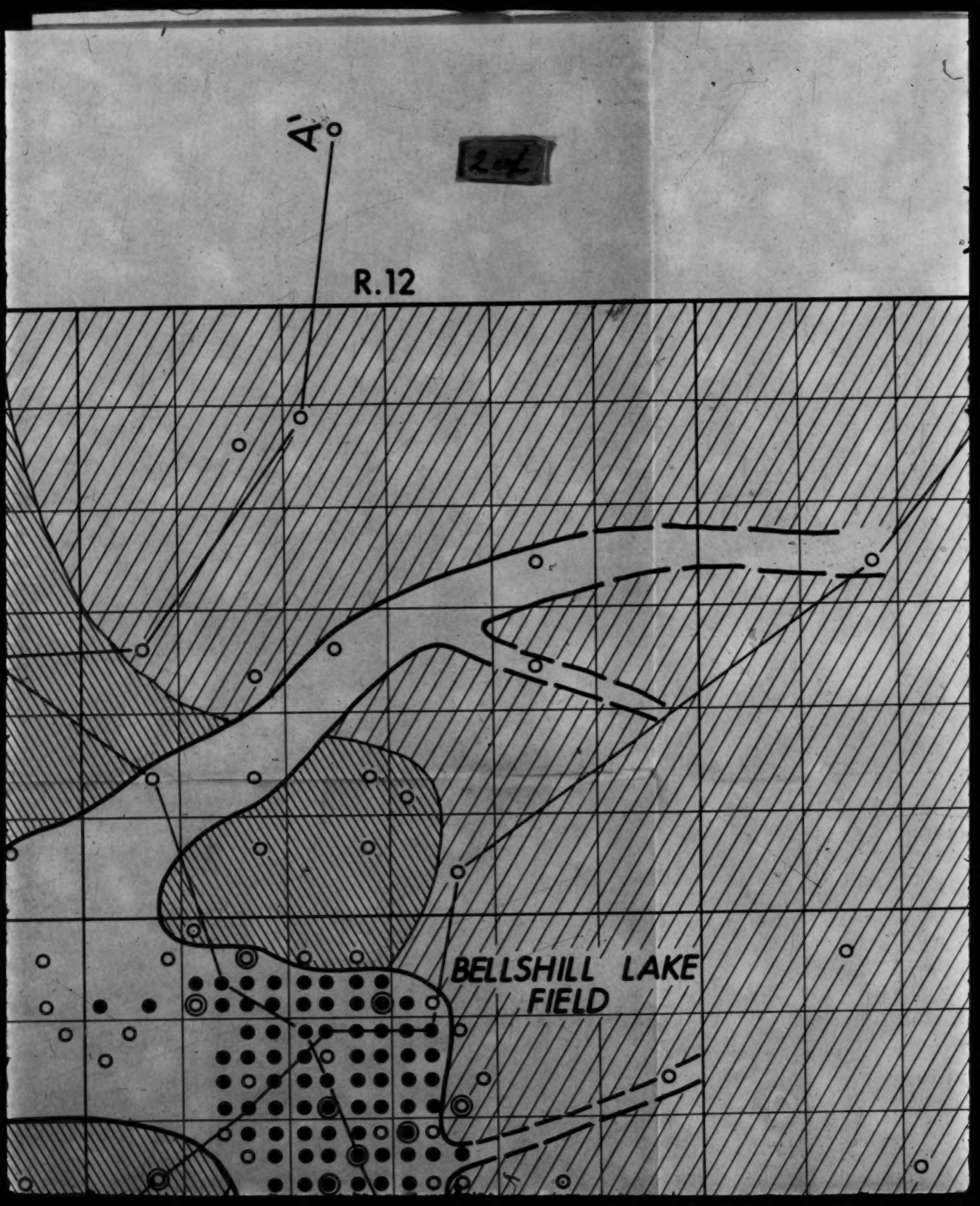
STRATIGRAPHIC CROSS SECTION IV.

KILLAM N° 10-4 to CPOG NW KESSLER N°7-7

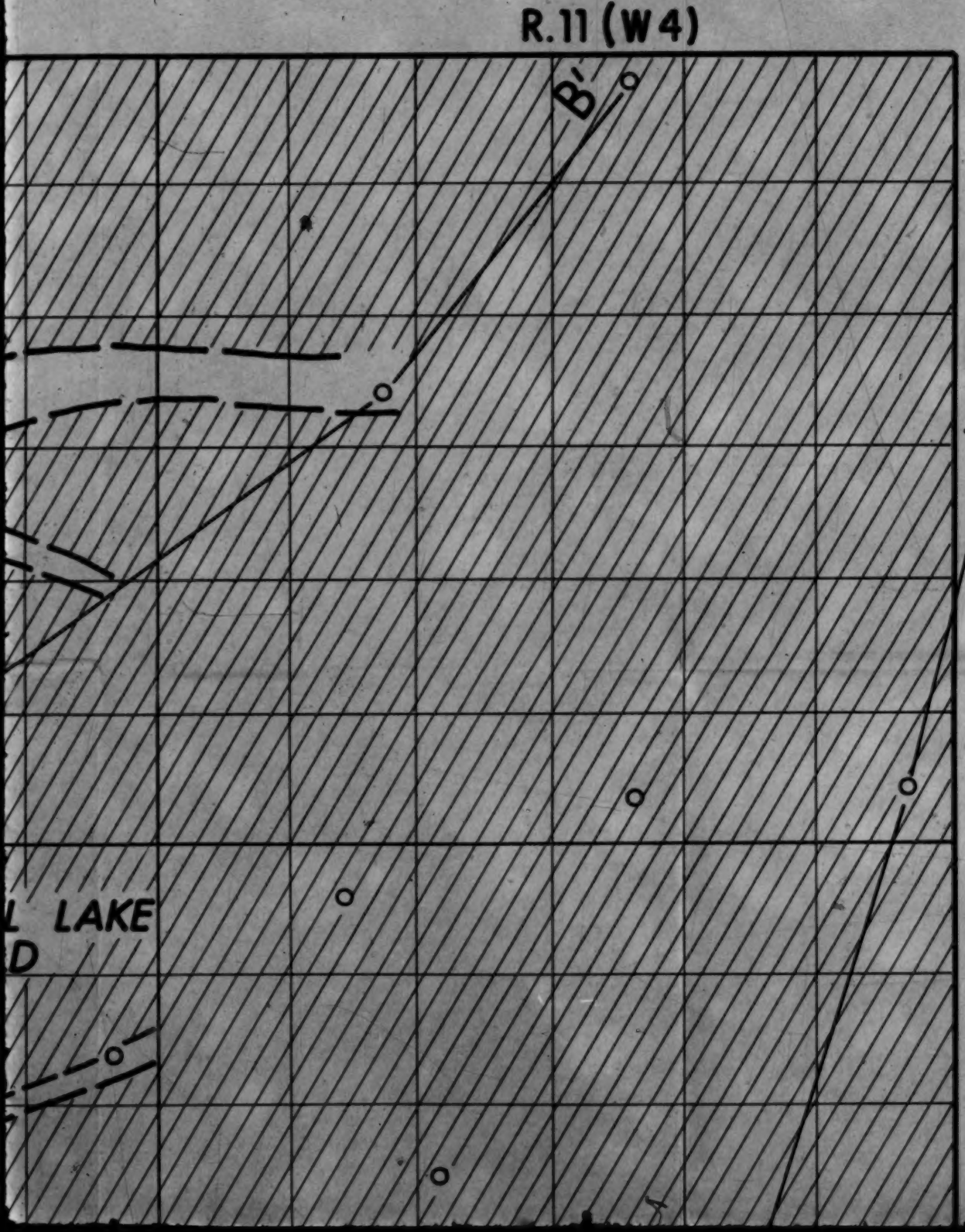
Vertical scale: 1"=100 ft., Horizontal scale: 1"= 0·5 mi.(exept when the distance between two wells is less than 1·57 mi.

G.L.Cartier, 1976


D
R.13
CROSS SECTION IV.
(Fig. 1)
(Fig. 4)


A'
2 of
R.12
BELLSHILL LAKE
FIELD

3 of



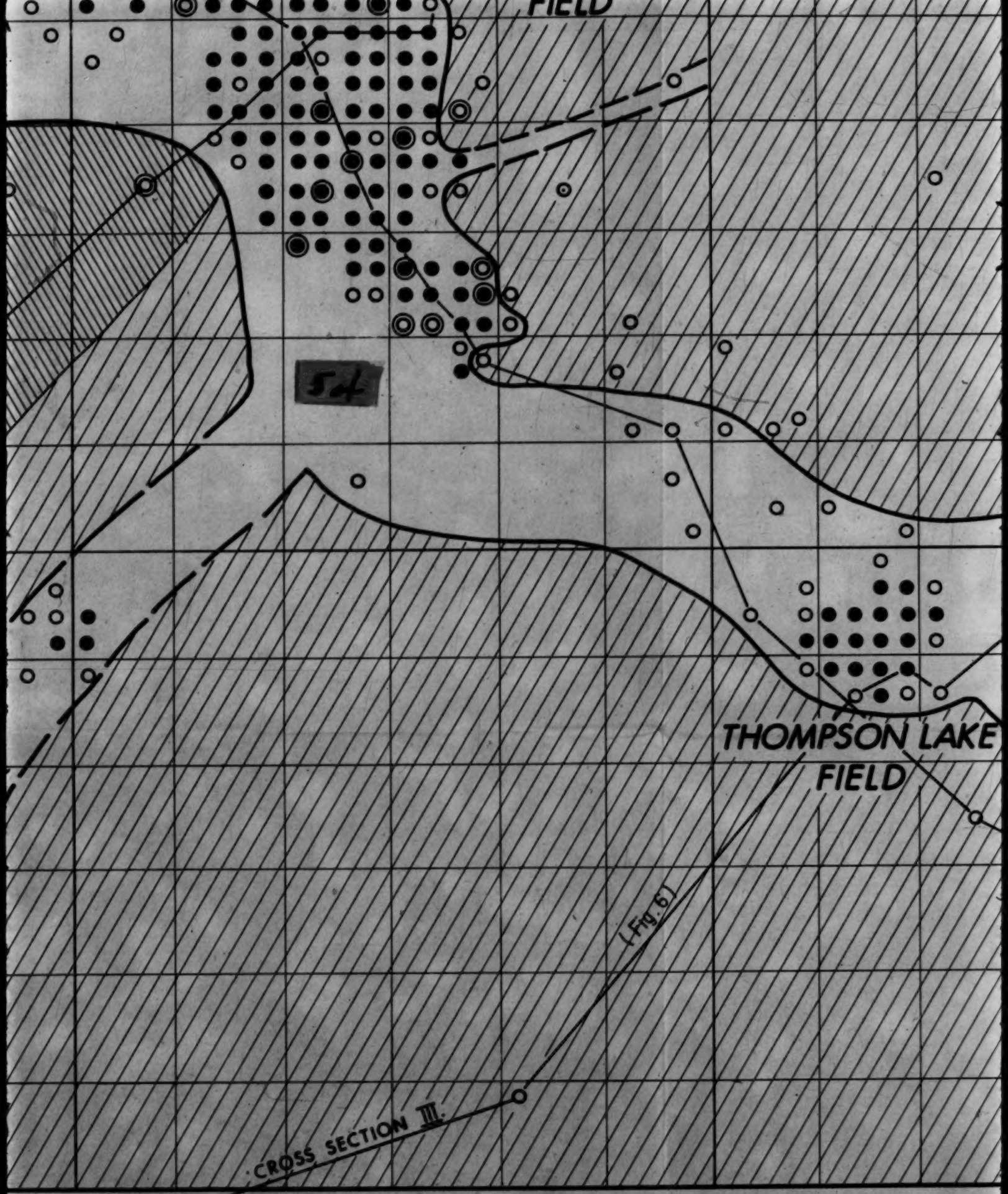
A

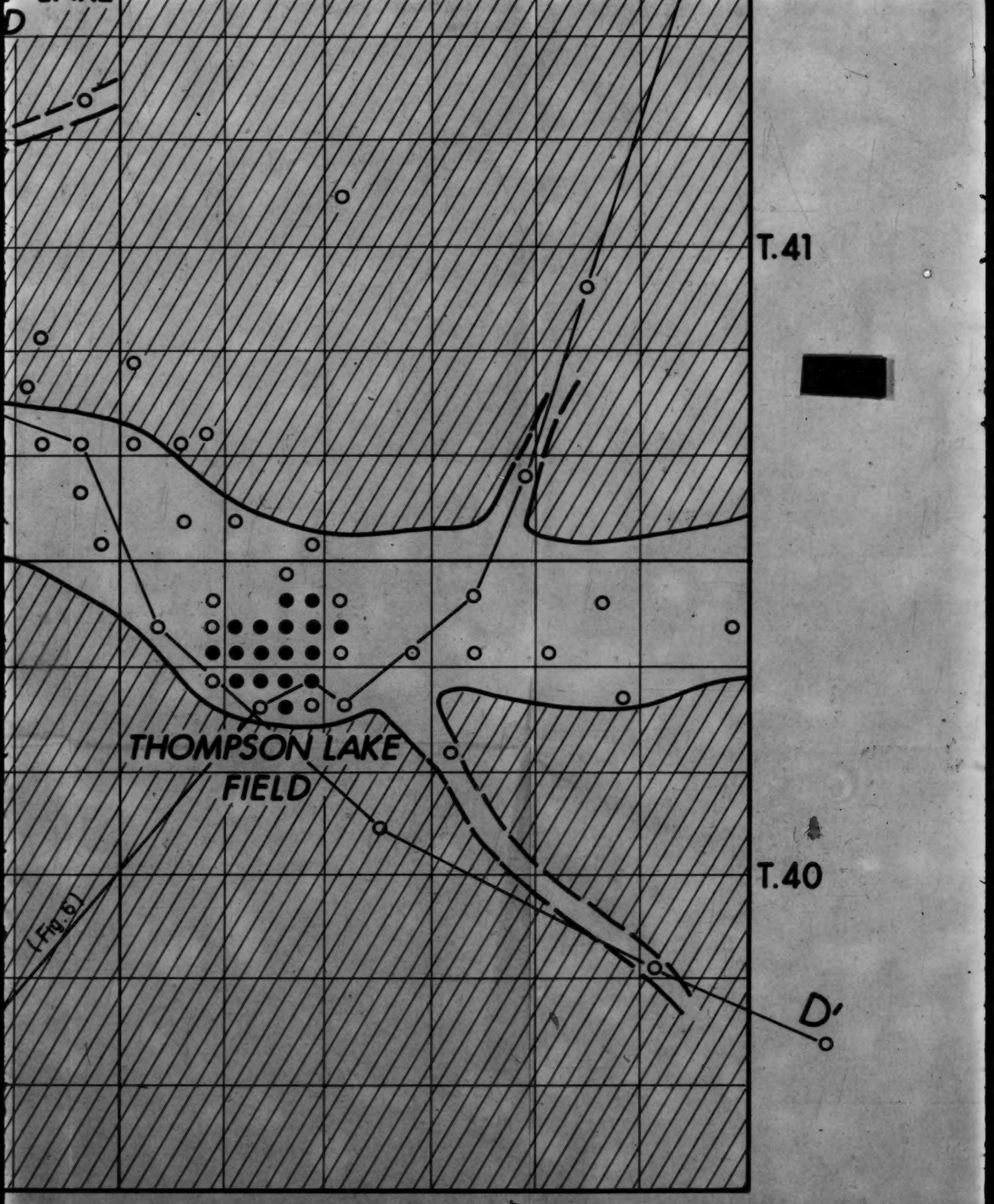
CROSS SECTION I. (Fig. 4)

B

CROSS SECTION II. (Fig. 5)

C


FIELD
THOMPSON LAKE
FIELD
(Fig. 6)
CROSS SECTION III.


D
T.41
THOMPSON LAKE
FIELD
T.40
(Fig. 6)
D'

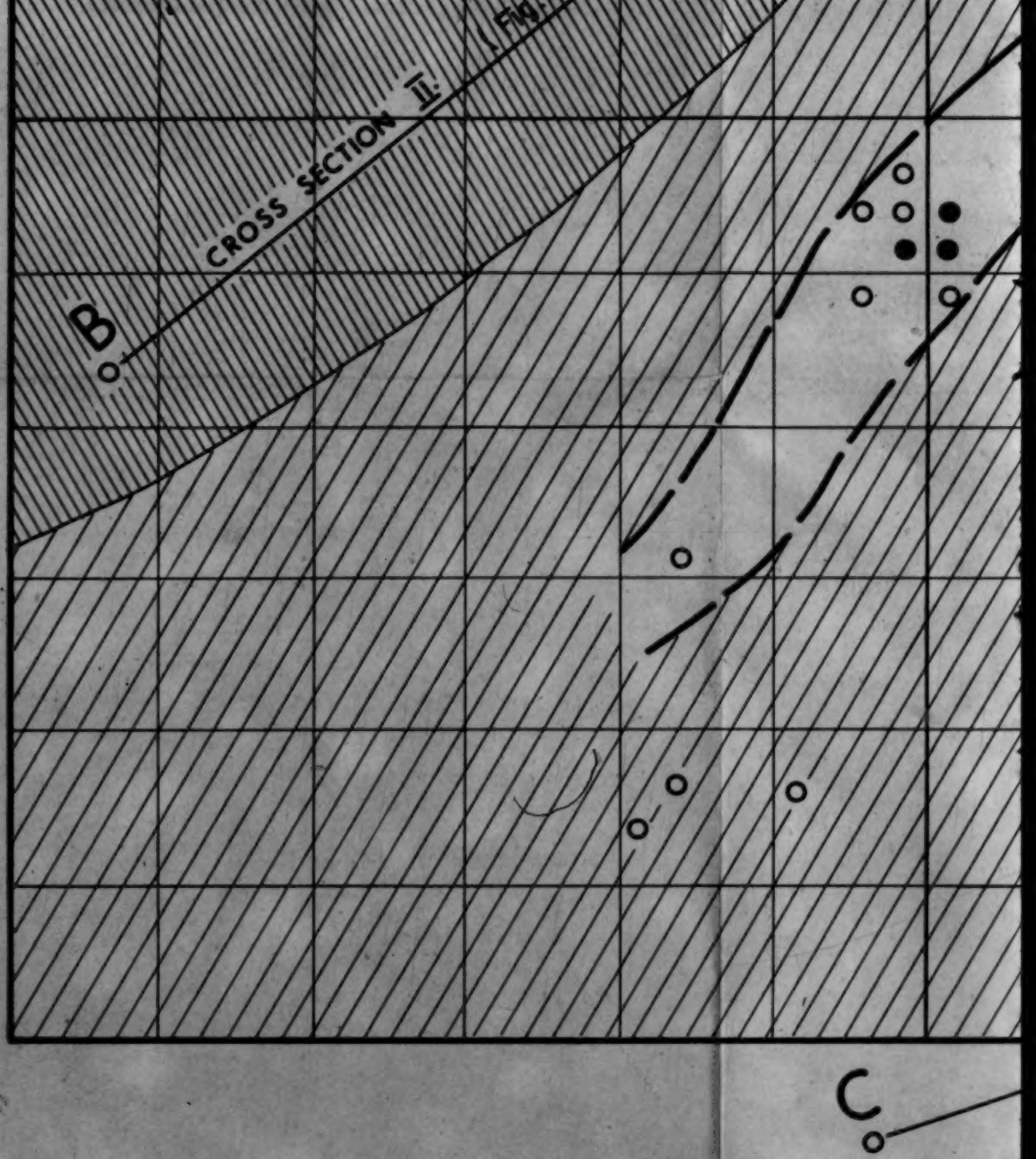
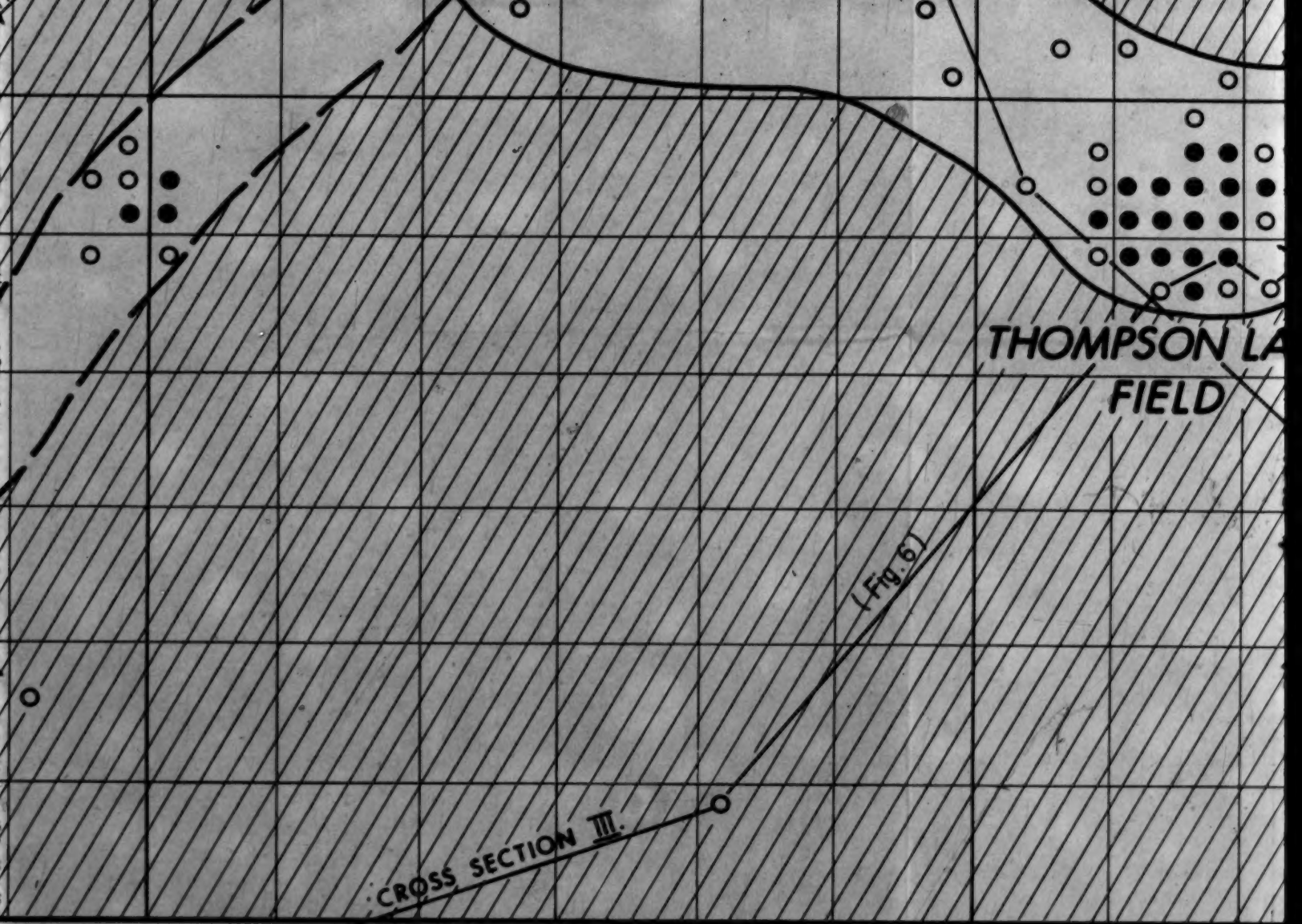


Figure 8.

"CALCAREOUS" MEMBER FACIES MAP S
POSITION OF CROSS SECTIONS.

BELLSHILL LAKE AREA, ALBERTA.



ES MAP SHOWING

IONS.

ERTA.

Shaly Facies (s

Detrital Facies

Channel Sands

Scale in mile

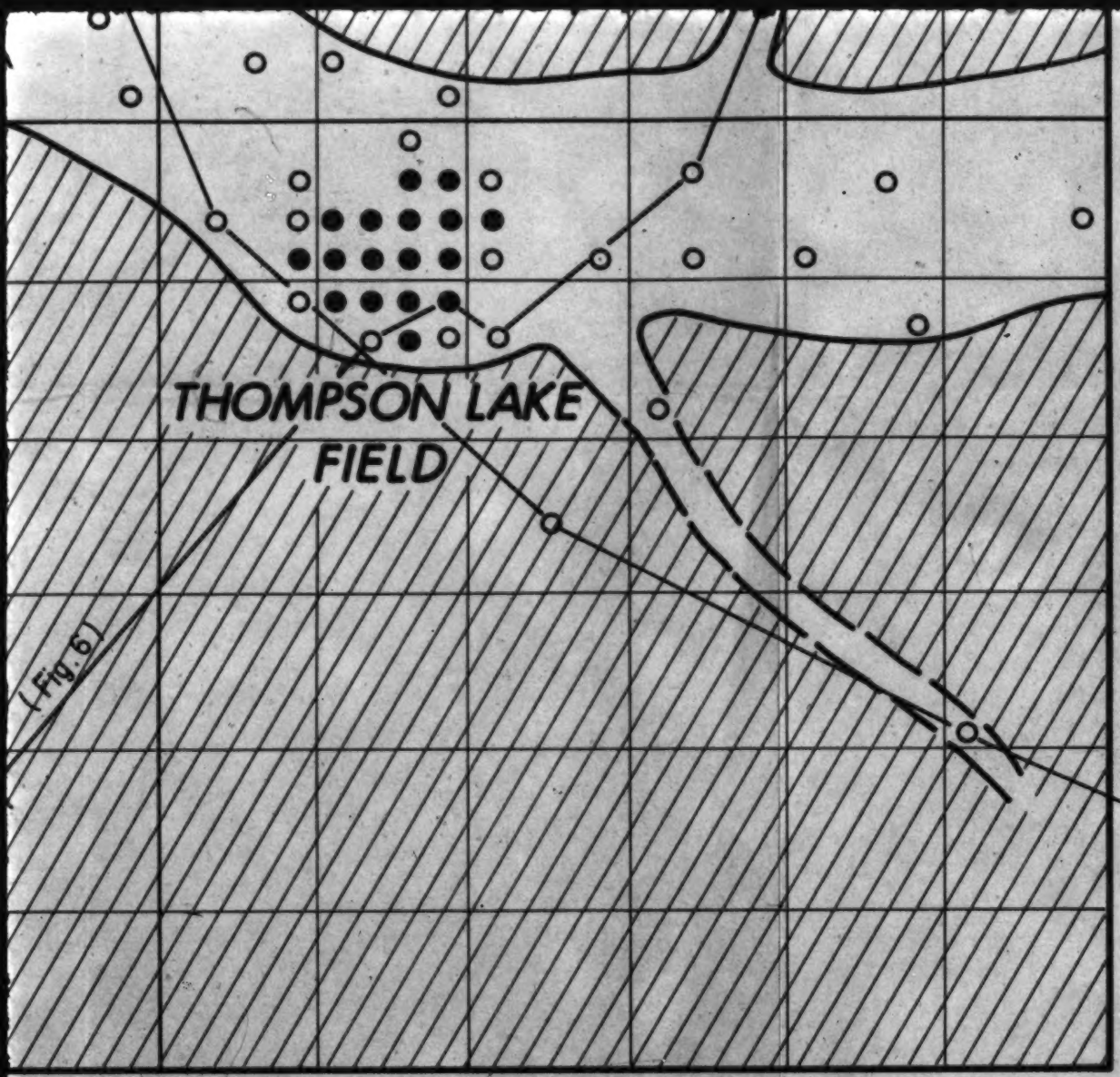
0 1 2

Wells producing from the Mannville

Wells dry in the Mannville

Cores examined

G.L. Cartier,



Shaly Facies (shale, limestone,...)

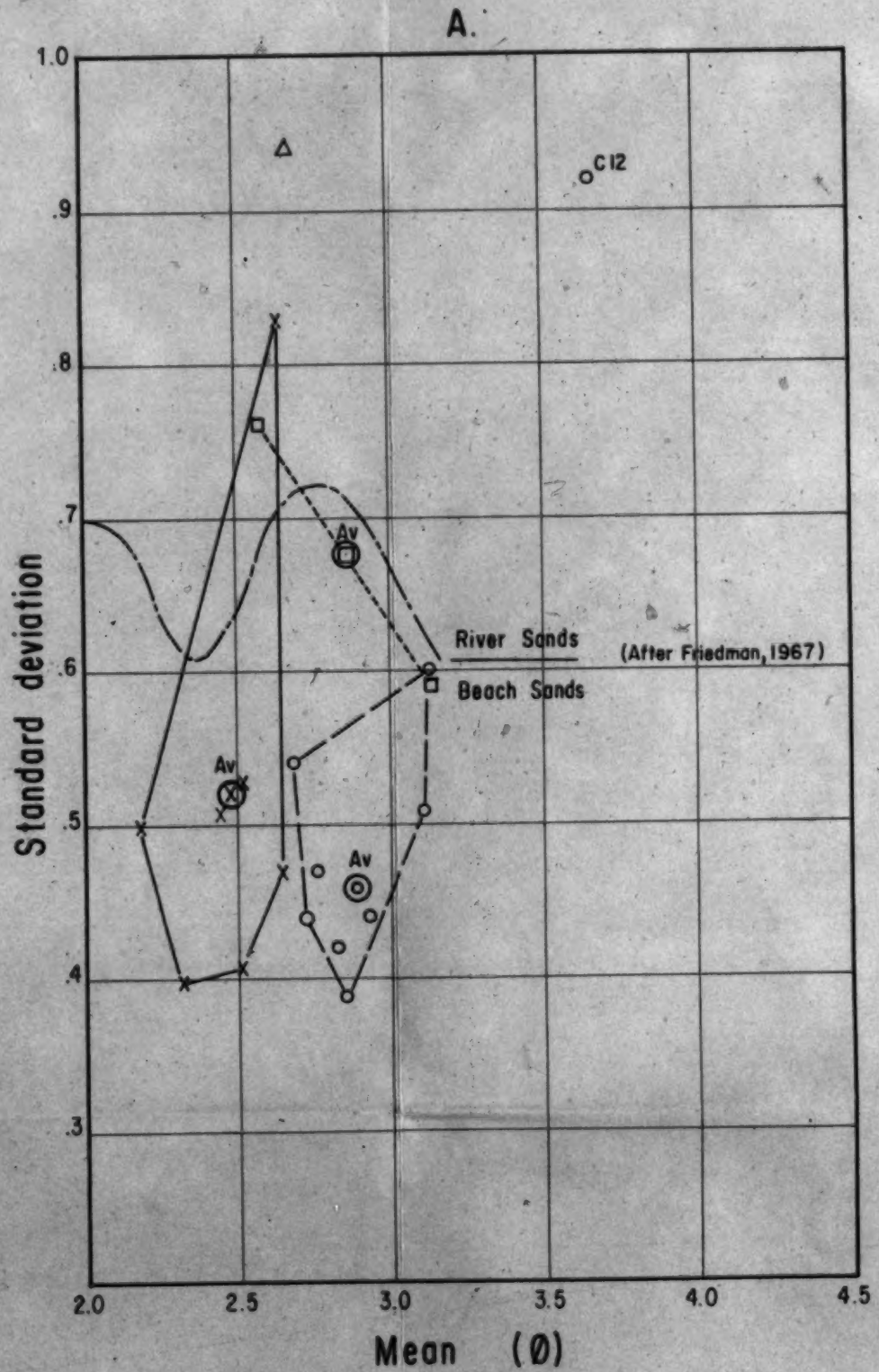
Detrital Facies (siltstone, shale,...)

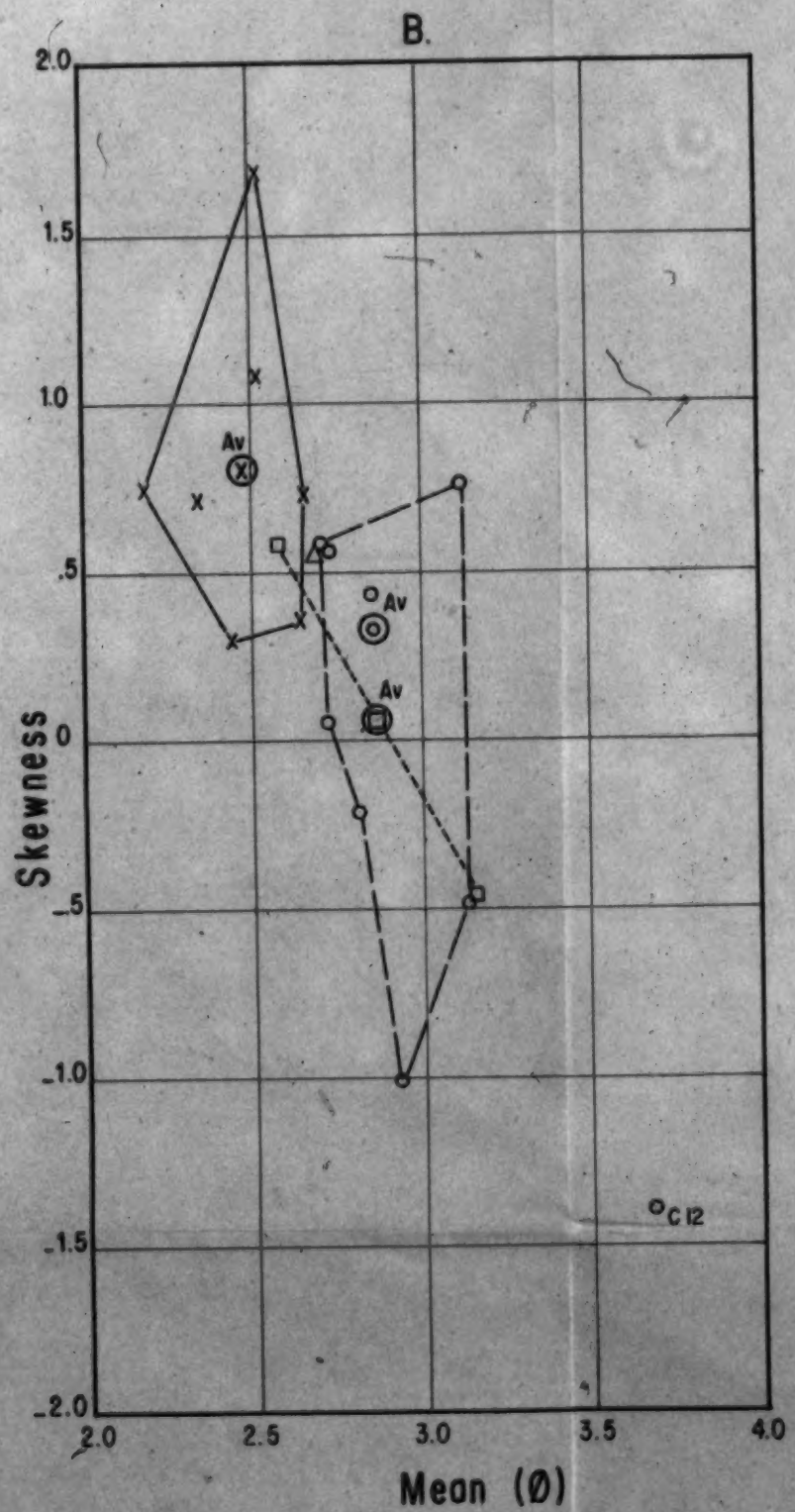
Channel Sandstones

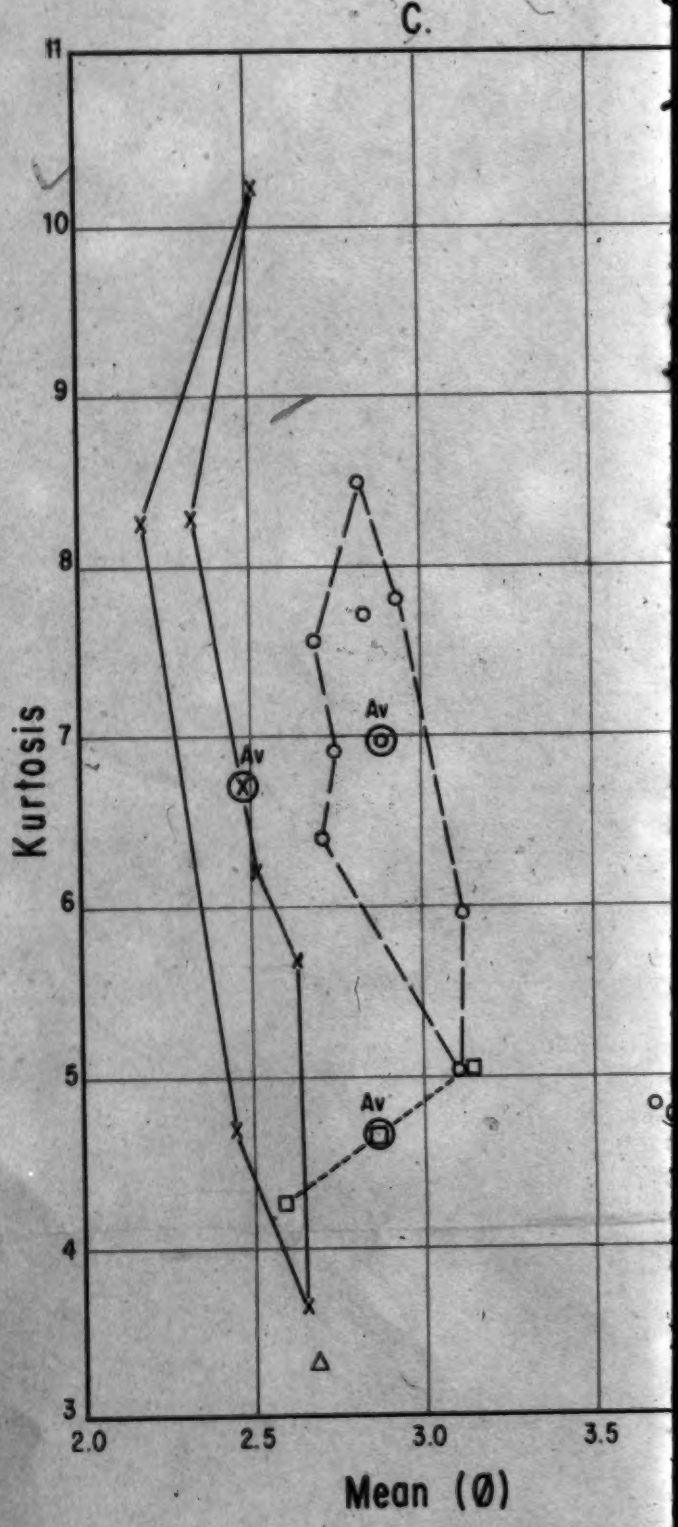
Scale in miles

0 1 2 3 4

G.L. Cartier, 1976


A.
Standard deviation
1.0
.9
.8
.7
.6
.5
.4
.3
2.0
2.5
3.0
3.5
4.0
4.5
Mean (Ø)
C12
Av
Av
Av
River Sands
(After Friedman, 1967)
Beach Sands
Skewness
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
2.0

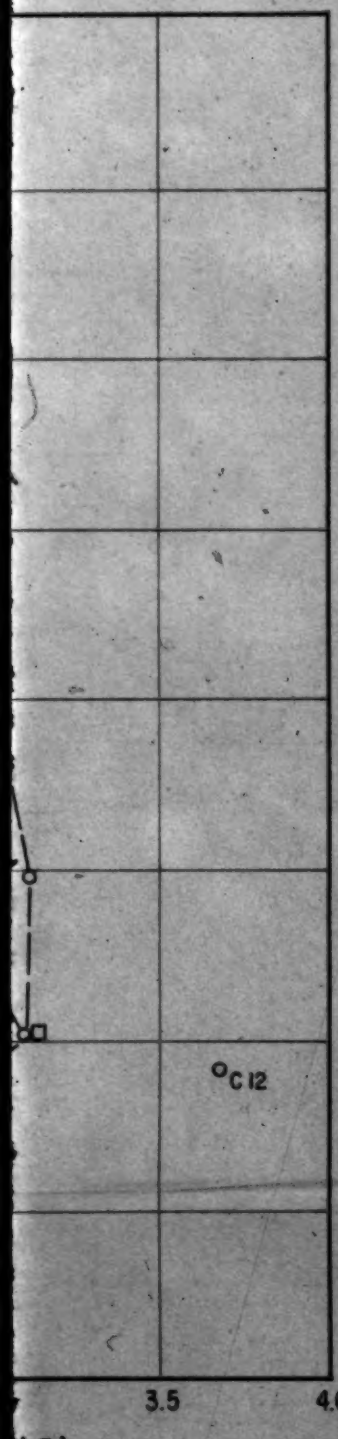

B.
Skewness
Mean (Ø)
Av
Av
Av
C12
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
2.0
2.5
3.0
3.5
4.0


C.
Kurtosis
Mean (Ø)
Av
Av
Av
11
10
9
8
7
6
5
4
3
2.0
2.5
3.0
3.5

3 of

Figure 13

PLOTS OF STATISTICAL SIZE PARAMETERS FOR ENVIRONMENTAL RECOGNITION _ COMPARISON WITH FRIEDMAN RESULTS (1961_1967)



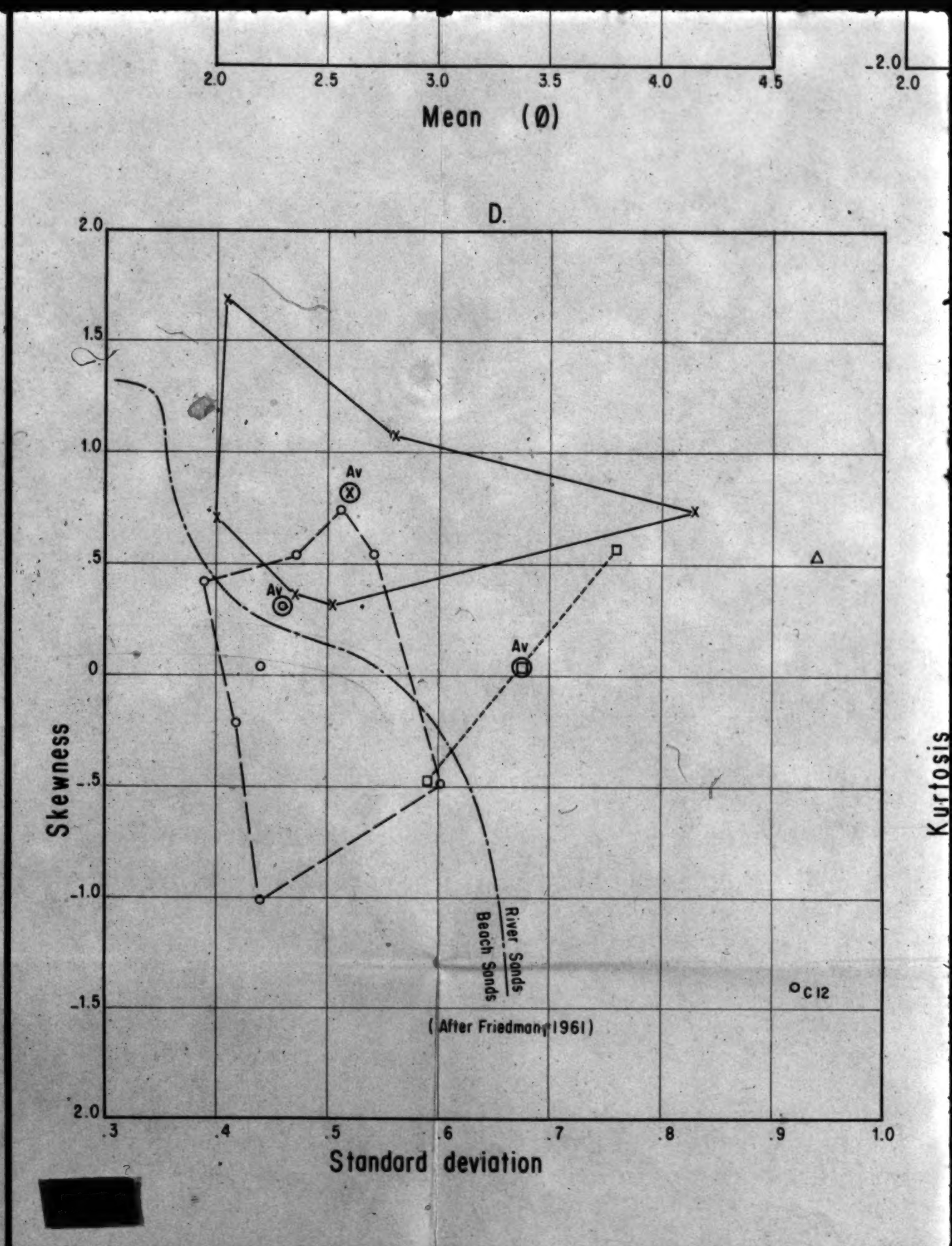
LEGEND

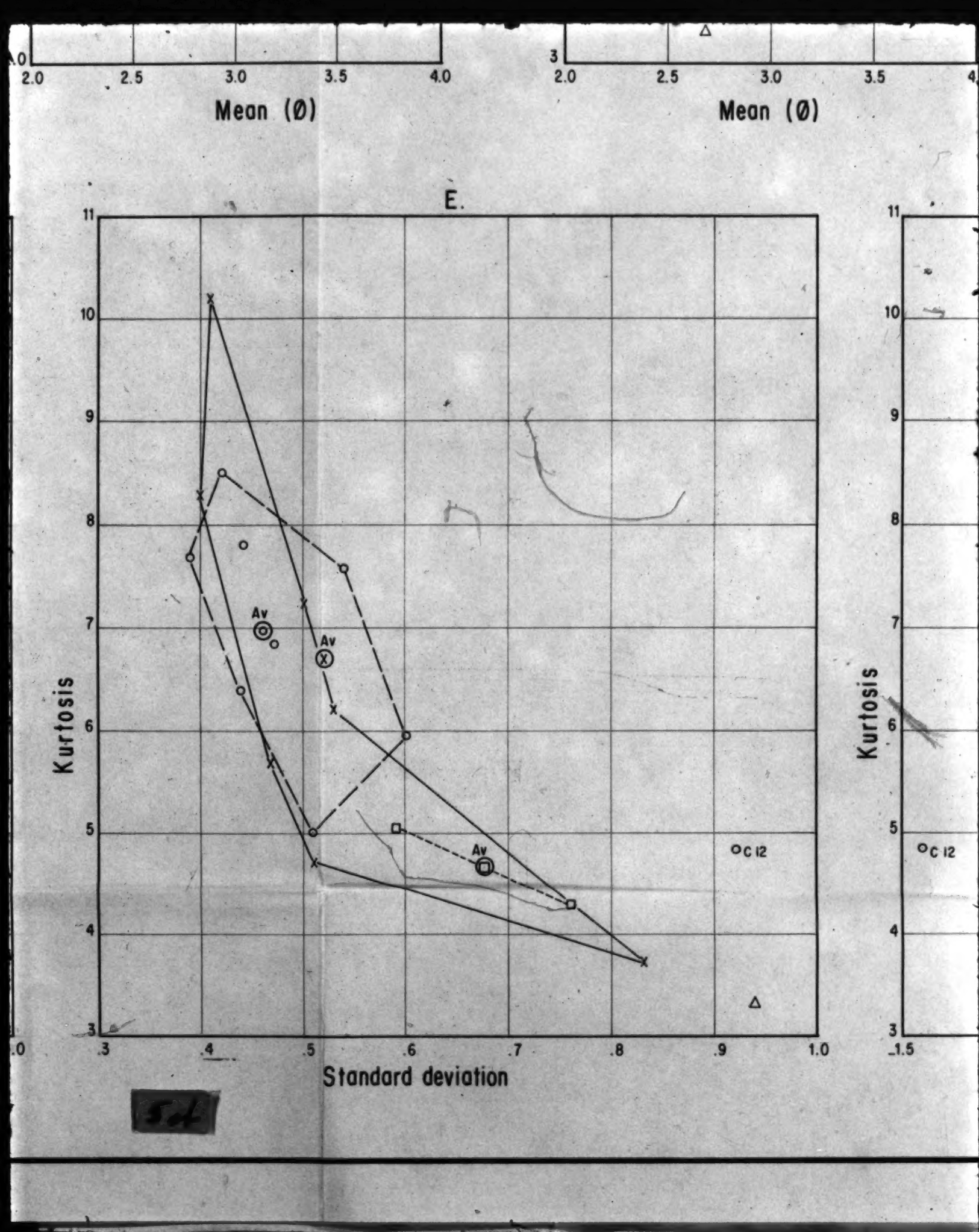
x ..... UNKNOWN

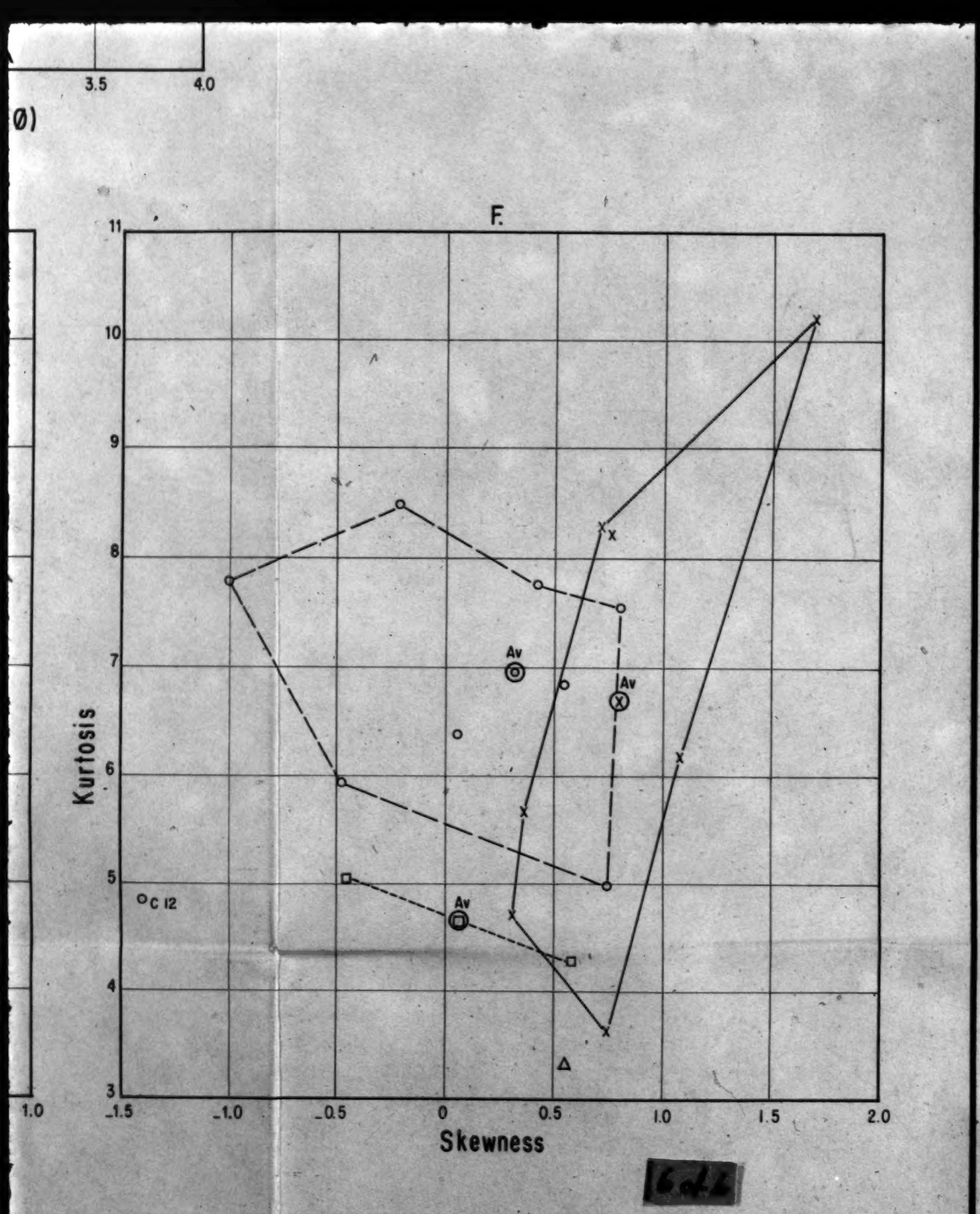
o ..... CHANNEL

Δ ..... "CALCAREOUS" mbr.

□ ..... ELLERSLIE Mbr.


2.0
2.5
3.0
3.5
4.0
4.5
Mean (Ø)
-2.0
2.0
D.
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
2.0
Skewness
Av
Av
Av
River Sands
Beach Sands
C 12
(After Friedman, 1961)
.3
.4
.5
.6
.7
.8
.9
1.0
Standard deviation
Kurtosis


2.0
2.5
3.0
3.5
4.0
Mean (Ø)
2.0
2.5
3.0
3.5
Mean (Ø)
E.
11
10
9
8
7
6
5
4
3
Kurtosis
Av
Av
Av
C 12
.3
.4
.5
.6
.7
.8
.9
1.0
Standard deviation
11
10
9
8
7
6
5
4
3
Kurtosis
C 12
-1.5


3.5
4.0
Ø)
F.
11
10
9
8
7
6
5
4
3
Kurtosis
Av
Av
Av
C 12
-1.5
-1.0
-0.5
0
0.5
1.0
1.5
2.0
Skewness
1.0
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